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February 9, 2011

Brian Timerson
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155

Kirk Rosenberger
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155

**Re: Revised Water Management Plans**
**Mesabi Nugget Phase II**

Dear Brian and Kirk:

On behalf of Mesabi Mining, LLC, enclosed please find the revised Proposed Water Management Plans. This revision is based on the recent project changes and is consistent with the other reports which will be submitted in the coming months. We are not submitting a "Response to Comment" document since no comments were received on the previous version.

If you have any questions they should be directed Keith Hanson at 218-590-2790 or via email at keh@barr.com.

Sincerely,

Mike Hansel, P.E.
Senior Chemical Engineer & Vice President
Enclosure

c: Rose Berens, Bois Forte
Margaret Watkins, Grand Portage Band
Nancy Schuldt, Fond du Lac Band
Nick Axtell, 1854 Treaty *electronic only*
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# *Proposed Water Management Plans*

## *Mesabi Nugget Phase II Project*

*Prepared for*
*Mesabi Mining, LLC*

*February 2011*

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## Mesabi Nugget Phase II Project

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### Mesabi Mining, LLC

### February 2011

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MESABI MINING
A new age of iron.

# Proposed Water Management Plans

## February 2011

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# 1.0 Introduction

## 1.1 Project Overview

The proposed Mesabi Nugget Phase II project (Project) is an integrated facility for the mining, crushing, and concentrating of taconite that will supply the Mesabi Nugget Phase I Large Scale Demonstration Plant (LSDP) taconite for iron nugget production. The Project will be located on the Mesabi Iron Range north of Hoyt Lakes, Minnesota (Figure 1). It will be entirely located on portions of the site of the former LTV Steel Mining Company (LTVSMC) facility (formerly known as the Erie Mining Company prior to 1986). The Project will be undertaken by Mesabi Mining, LLC. The Project will provide iron concentrate for use in the previously permitted LSDP, which began operations in January 2010 at the Project site. The Project will reopen the Area 2WX and Area 6 Pits. Additionally, a new pit, referred to as the Area 6NW Pit, will be developed north of the existing Area 6 Pit (Figure 1). Mining and waste rock management is described in detail in the Preliminary Mine, Stockpile and Material Handling Plan (Barr, 2011a).

## 1.2 Description of Project Alternatives

Two mining alternatives are currently under consideration. As required by Minnesota environmental review rules (Minnesota Rules, part 4410.2300), a No Action (i.e. no mining) Alternative is also considered in this report. The mining alternatives are:

1) Mining Alternative 1, in which the Area 2WX Pit and Area 6 Pit will be mined, with additional mining taking place in the Area 6NW Pit, and

2) Mining Alternative 2, in which only the Area 2WX and the Area 6NW Pits will be mined.

Under all of the Project alternatives, the Area 1 Pit will be used for water supply and water treatment for the LSDP (and for tailings disposal in the western end of the pit under Mining Alternatives 1 and 2; Barr, 2011a). Currently, the water level of the Area 1 Pit is being maintained at an elevation to prevent an uncontrolled seep in the southeastern corner of the pit and to provide for storage as required by the current NPDES permit (Barr, 2011b).

### 1.2.1 Mining Alternative 1

Mining Alternative 1 consists of dewatering and mining in the Area 2WX and the Area 6 Pits, with limited mining in the Area 6NW Pit (Barr, 2011a). Under this alternative, mining will commence in the Area 6NW Pit and will produce high-quality Lower Cherty ore during the first 10 years of the project.  Limited mining of Area 6NW will also continue during the last 10 years of the project.  The Area 2WX Pit will be dewatered to the St. Louis River.  Mining in Area 2WX will then take place for the rest of the 20-year operational period and will produce Upper Cherty ore (Barr, 2011a).  The third source of ore will be the Area 6 Pit, which will provide Lower Cherty ore.  The Area 6 Pit will also be dewatered and discharged to the St. Louis River (Barr, 2011b).  Once mining has been completed, dewatering from the merged Area 6 Pit and Area 6NW Pit and the Area 2WX Pit will cease and the pits will refill (Barr, 2011b).  The anticipated pit refilling rates are presented in the Mine Pit Hydrogeology and Water Balances report (Barr, 2011b).

The Area 1 Pit will be used as a process water supply and for tailings placement (in the western half of the Pit).  The Area 9 Pit will be used for subaqueous disposal of Lower Slaty waste rock (Barr, 2011a).  The water level of the Area 9 Pit will be lowered to accommodate rock disposal and to remove water displaced by waste rock placement.

### 1.2.2 Mining Alternative 2

Mining under Alternative 2 is restricted to Area 2WX and Area 6NW (Barr, 2011a).  There will be no mining in the Area 6 Pit; however, the pit water level will be drawn down ("dimpled") to induce an inward gradient toward the pit in order to minimize subsurface outflow which is currently occurring (Barr, 2011b).  Mining will commence in the new Area 6NW Pit and continue throughout the first ten years of the project.  During the last ten years of this alternative, the scheduled production will come solely from the Area 2WX Pit (Barr, 2011a).  Mining in the Area 2WX Pit under Mining Alternative 2 will be similar to that described for Alternative 1, but with a slightly expanded pit footprint.  Once mining has been completed, the Area 6NW and 2WX Pits will be allowed to refill.  The anticipated pit refilling rates are presented in the Mine Pit Hydrogeology and Water Balances report (Barr, 2011b).

Similar to Mining Alternative 1, the Area 1 and Area 9 Pits will be used as a process water supply and tailings disposal, and for subaqueous waste rock disposal, respectively.

### 1.2.3 No Action Alternative

Under the No Action Alternative, no mining will occur as part of the Project, and concentrate will be acquired from other sources on the open market.  As a result, storage for tailings and waste rock will not be needed in the Area 1 or Area 9 Pits.  However, the LSDP will operate, and the Area 1 Pit will be used for process supply water and for water treatment.

### 1.2.4 Legacy Mitigation

Under Mining Alternatives 1 and 2, Mesabi Nugget proposes the following mitigation of legacy water quality issues:

- Pumping water from Area 1, 2WX and 6 Pits to the St. Louis River (as described above) at a rate based on the flow of water and the specific conductance of the St. Louis River so that water quality standards are met at the regulatory compliance boundary (e.g. edge of mixing zone or end of pipe);
- Improved covering and/or subaqueous disposal (in Area 1 and 6 Pits), of legacy lower Slaty waste rock piles 1054, 6011, 6014 and 6015; and
- Assess treatment or alternative water supply for the city of Aurora to meet secondary drinking water standards.

The exact method of mitigation and the design of that mitigation will be determined during a series of studies and field tests during the first several years following issuance of permits. Because the exact methods, schedule and design of the mitigation will not be known until after the completion of the studies, a quantitative analysis of the impacts of the mitigation is not possible. Rather, a qualitative analysis of potential impacts of the mitigation will be discussed for each alternative.

Under the No Action Alternative, legacy mitigation will be negotiated as part of the reissued Permit to Mine and NPDES permits in closure. Legacy mitigation may include some of the mitigation described above for the Project; however, scope, timing and extent may be different if mining does not occur at the site.

## 1.3 Report Objectives

The Minnesota Department of Natural Resources (MDNR), together with the United States Army Corps of Engineers (USACE), is preparing a joint state-federal Environmental Impact Statement (EIS) for the Project. This report is prepared in support of the EIS, and presents the plans for water management under each of the Project alternatives. Water management will be required for mining in the Area 2WX, Area 6 Pit, and Area 6NW Pit; for subaqueous disposal of waste rock in the Area 9 Pit, water supply and water treatment used by the LSDP and a newly constructed concentrator, for tailings management and disposal in Area 1 Pit, and for management of legacy water quality issues (Figure 1). The water management plans presented in this report are designed to manage water during Project operations, while minimizing water quality and water quantity impacts to receiving waters (Barr, 2009a; Barr, 2011c; Barr, 2011d; Barr, 2011i). Although water quantity impacts to receiving waters were considered during the development of these plans, those impacts are not presented or discussed in this report.

## 1.4 Report Organization

Section 2.0 provides contextual background for the water management plans, including a brief review of the existing National Pollutant Discharge Elimination System (NPDES) water discharge permits (Section 2.1), and a discussion of the motivation for proposed pumping of Project waters to the St. Louis River (Section 2.2). Section 3.0 describes the manner in which water management plans for the Project alternatives were developed. The remainder of the report presents water management plans for each mining alternative (Sections 4.0 and 5.0), as well as for a No Action Alternative (Section 6.0). Impacts of legacy mitigation efforts will be qualitatively described for each mining alternative as well as for the No Action Alternative.

# 2.0 Background

## 2.1 Existing Discharge Permits and Water Quality

The existing NPDES permits will need to be modified for the Project. Under NPDES Permit MN0069078, Mesabi Mining is currently permitted to discharge 5.0 million gallons per day (MGD) to 7.2 MGD to Second Creek via each of the following outfalls: SD014, SD015, SD016, and SD017. An additional 5.0 MGD to 7.2 MGD are permitted to be discharged to Unnamed Creek via each of the following outfalls: SD018, SD019, SD020 and SD021. Water from the outfalls ultimately discharges to the Partridge River, via either Unnamed Creek or Second Creek.

Baseline monitoring required for the EIS has revealed that water in some of the mine pits and surface water streams within the Project area have elevated concentrations of sulfate and associated neutralization products: alkalinity, total dissolved solids (TDS), specific conductance, and hardness (Barr, 2011e). Some of these surface water bodies do not meet water quality standards (Barr, 2011d) Additionally, toxicity testing required under the existing NPDES permit has demonstrated that the current water in the Area 1 Pit and Area 2WX Pit is intermittently toxic to *Ceriodaphnia Dubia* (*C. Dubia*; Barr, 2011f, Barr, 2009c, and Barr, 2009d). Operation of the LSDP and its associated water treatment system is expected to improve the hardness of the discharge; however, concentrations of TDS, specific conductance, sulfate, and alkalinity in the discharge are expected to increase (Barr, 2011d).

Similarly, the water in the Area 6 Pit does not currently meet Class 3 and 4 standards for hardness, TDS, specific conductance, and alkalinity if applied to this surface water (Barr, 2011e). Sulfate concentrations are higher than in the Area 1 Pit, and regulatory and cooperating agencies have raised concerns regarding methylmercury formation in adjoining wetlands (Barr, 2009e) and impacts on wild rice in the Partridge River and downstream in the St. Louis River. Toxicity testing has demonstrated that the water from the Area 6 Pit is chronically toxic to *C. Dubia (*Barr, 2011f and Barr, 2009c). Currently, outflow from the Area 6 Pit is occurring via shallow groundwater flow in the direction of Second Creek (Barr, 2011b). While the existing NPDES permit (MN0069078) allows a surface water discharge to Second Creek, it contains no effluent limits or variances for the pollutants regulated under Class 3 and 4 standards.

## 2.2 Proposed St. Louis River Discharge

Discharge of water from the pits was originally proposed to utilize outfalls already permitted under the existing NPDES permits. Water treatment to address the parameters which exceed water quality standards in the Area 1 Pit and Area 6 Pit is not feasible nor cost effective (Barr, 2011g; Barr, 2011h; Engesser, 2010). The MPCA decision in February 2010 to strictly enforce a 10 mg/L standard for mining projects such as this project, in waters used for the production of wild rice (a policy which has not been enforced since the rules were established in 1973), and the discovery of wild rice in the Partridge River in the fall of 2009 (Barr, 2009f), effectively precludes a discharge to the Partridge River. Therefore, a discharge to the St. Louis River is proposed, which would allow discharge of pit waters without the need for variances or treatment.

The water management plans for the mining alternatives presented below (Sections 4.0 and 5.0) propose using a hydrograph-controlled discharge approach to pump water from the Area 1 Pit to the St. Louis River during Mining Alternative 1 and Mining Alternative 2 in order to meet water quality standards (including chronic toxicity) without the need for variances or treatment. Protection of Class 2 uses and compliance with water quality standards can be achieved by pumping the water from the Area 1 Pit to the St. Louis River at a rate which meets water quality standards for all pollutants, including Class 3 and 4 standards as well as the Class 2 standards for chronic toxicity at the discharge point (Barr, 2011i). Similarly, protection of Class 2 uses and compliance with water quality standards can be achieved by pumping water from the Area 2WX and Area 6 Pits to the St. Louis River during Mining Alternatives 1 and 2 to prevent shallow groundwater outflow to Second Creek. In both cases, acute toxicity and mercury standards will be met at the discharge point without a mixing zone.

The proposed water management plans for both mining alternatives (described in Sections 4.0 and 5.0) move the permitted outfalls from Unnamed Creek and Second Creek directly to the St. Louis River in order to comply with applicable water quality standards (Figure 1). Under the existing permits, a total of 40.0 to 57.6 MGD may be discharged to Unnamed Creek and Second Creek. Mesabi Mining is proposing to pump up to 28.8 MGD (20,000 gallons per minute [gpm] or 44.5 cubic feet per second [cfs]) from the Area 1 Pit, the Area 2WX Pit and the Area 6 Pit down a pipeline directly to the St. Louis River (Figure 1; Barr 2011e).

The proposed monitoring strategy to implement the water management plans is described further in Appendix A.

# 3.0 Pumping Rates and Drawdown Estimates

The pumping rates and drawdown estimates presented in the water management plans are based primarily on the water balances presented in the Mine Pit Hydrogeology and Water Balance report (Barr, 2011b) and in the St. Louis River Water Quality report (Barr, 2011i), respectively. Geomorphologic impacts were also considered in designing the water management plan and were based on information presented in the Surface Water Hydrology Study (Barr, 2011c). The water management plans include pits from which or to which water will be appropriated and transferred to other pits or discharged to surface water bodies, including Second Creek and the St. Louis River.

## 3.1 Water Management Concept

Because periods of low flow in the St. Louis River may not allow the desired rate of initial and/or maintenance dewatering of all the pits, a strategy was developed that prioritizes pit dewatering and minimizes storage. It is assumed that a 30 inch diameter pipe with 21,500 gpm capacity will serve the dewatering needs of the Area 1 Pit, Area 2WX Pit, and Area 6 Pit. The discharge point on the St. Louis River will be downstream of the wild rice on Second Creek and the Partridge River and downstream of the wild rice on the St. Louis River. See Figure 1.

Seasonal dewatering of the Area 2WX Pit directly to Second Creek was initially considered, outside of the wild rice critical period, but was dismissed due to potential environmental impacts (e.g. obtaining a variance for bicarbonate, dewatering impacts on Second Creek morphology, etc.) and lack of benefit in dewatering times. Therefore, the water management plans for Mining Alternatives 1 and 2 are based on dewatering to the St. Louis River. However, pumping of Area 1 Pit, Area 2WX Pit, and Area 6 Pit to the St. Louis River will remove most of the flow from Second Creek, resulting in low flows (7Q10) of near zero.

## 3.2 Water Management Priorities

For pit dewatering, it is assumed that first priority is given to the maintenance dewatering from the Area 1 Pit. If there is assimilative capacity remaining in the pipe and the St. Louis River, second priority is given to the dimpling of the Area 6 Pit. Excess water accumulating in these pits that cannot be sent to the St. Louis River due to lack of capacity in the river, is allowed to accumulate in each pit. The dimpling of Area 6 Pit includes sufficient storage capacity such that under average climate conditions, the periodic accumulation of water in the Area 6 Pit does not cause the pit water level to rise above 1450 ft (the projected level of pit outflow to the subsurface), including storage of excess water from Area 2WX. Similarly, water level in Area 1 Pit will be lowered so that there is sufficient storage volume while still preventing subsurface outflow through the southeast seep of Area 1 Pit.

After the dimpling of the Area 6 Pit and maintenance dewatering of the Area 1 Pit are achieved, the Area 2WX Pit is dewatered to the St. Louis River via any additional capacity available in the pipe and the river. Following the initial dewatering of the Area 2WX Pit, excess water accumulating in the pit that cannot be dewatered to the St. Louis River is routed to the Area 6 Pit, which will provide temporary storage.

During Mining Alternative 1, any additional capacity in the pipe and river following the dimpling of the Area 6 Pit, maintenance dewatering of the Area 1 Pit, and the initial and maintenance dewatering of the Area 2WX Pit is dedicated to the full dewatering of the Area 6 Pit.

## 3.3 Assimilative Capacity of the St. Louis River

The amount of water from each pit that can be routed to the St. Louis River depends on the resulting water quality, and is thus dependent on the flow rates and chemistry of four critical constituents from each source (alkalinity, hardness, specific conductance, and total dissolved solids). This analysis assumes that the allowable concentration of the following four parameters after mixing is less than 80 percent of the applicable water quality standards: alkalinity, hardness, specific conductance, and Total Dissolved Solids (TDS). In the MPCA meeting on August 27, 2009, MPCA staff requested that 80% or less of the available assimilative capacity be used for the Mesabi Mining and Mesabi Nugget discharges. Note that only the most limiting pollutant will consume 80% of the assimilative capacity. Generally, less than 10% of the assimilative capacity of the St. Louis River will be consumed for most pollutants.

With discharges from the three pits limited to 80% of the St. Louis River capacity for alkalinity, hardness, specific conductance and TDS, extensive toxicity testing has demonstrated that the $IC_{25}$ – the level at which young reproduction is reduced by 25% - the compliance point for toxicity – can be met at the edge of the mixing zone. By limiting the discharge to 80% of the St. Louis River capacity for the numeric Class 3 and 4 standards, the discharge makes up less than 18% of the flow in the river. See Table 3-1 for Alternative 1 and Table 3-2 for Alternative 2. All of the toxicity testing shows that the pits individually or combined have an $IC_{25}$ at 32% or greater dilution. Therefore, there is adequate margin for meeting the chronic toxicity standards. See Figure 2 and Figure 3 for graphical representation of Alternative 1 and Alternative 2.

**Table 3-1 Components of St. Louis River flow during Mining Alternative 1**

| Years | Average River Flow (cfs) | Average River Flow (gpm) | Percentage of River Flow | | | | |
|---|---|---|---|---|---|---|---|
| | | | Area 1 Pit | Area 2WX Pit | Area 6 (dimpling) | Area 6 (dewatering) | All Pits |
| 0-5 | 295.1 | 132,500 | 8.54% | 3.87% | 4.67% | 0.91% | 17.99% |
| 5-10 | 236.7 | 106,200 | 9.01% | 0.90% | 4.03% | 3.28% | 17.22% |
| 10+ | 213.9 | 96,000 | 1.11% | 3.78% | 8.63% | 0.42% | 13.95% |

**Table 3-2 Components of St. Louis River flow during Mining Alternative 2**

| Years | Average River Flow (cfs) | Average River Flow (gpm) | Percentage of River Flow | | | | |
|---|---|---|---|---|---|---|---|
| | | | Area 1 Pit | Area 2WX Pit | Area 6 (dimpling) | Area 6 (dewatering) | All Pits |
| 0-5 | 293.9 | 131,900 | 8.50% | 4.34% | 5.05% | 0.00% | 17.89% |
| 5-10 | 230.6 | 103,500 | 9.09% | 0.39% | 6.27% | 0.00% | 15.74% |
| 10+ | 192.0 | 86,200 | 1.12% | 3.36% | 9.34% | 0.00% | 13.82% |

The discharge rates from the pits are based on the rates presented in the Mine Pit Hydrogeology and Water Balances report (Barr, 2009g). Although these rates are not the same as the updated Mine Pit Hydrogeology and Water Balances report (Barr, 2011b), they are similar and provide a valid basis for this analysis. Similarly, the water quality in each of the pits are based on the concentrations presented in the Dissolved Solids and Chemical Balance report (Barr, 2009b) rather than the updated report (Barr, 2011d). The St. Louis River Water Quality Impacts report (Barr, 2011i) serves as a check on the environmental impacts from the water management plans. Further, the implementation of the water management plans will be based on monitoring data rather than predictions, ensuring that the environmental impacts will not exceed those presented in this and associated reports.

Water quality in the St. Louis River is based on the 2010 monitoring conducted by Mesabi Nugget. The St. Louis River flows used in this analysis are from the USGS gage located downstream of the confluence with the Partridge River. The analysis was replicated using each year from 1942 through 1980 as the starting year in the flow record to account for climate variability. Thus, maximum, minimum, and average values are returned for dewatering times and maximum pit storage.

## 3.4 Proposed Determination of St. Louis River Discharge Rate

Ideally, in order to ensure compliance with water quality standards during discharge into the St. Louis River, the limiting chemical parameters would be measured in real-time in both the receiving and the discharged waters (Barr, 2009h). Total hardness, alkalinity, TDS, sulfate, and toxicity are the limiting parameter for discharge. However, because they cannot be monitored in real time due to technological constraints, a method of near instantaneous water quality parameter estimation has been developed based on simple linear regression models. These models use flow and specific conductance as indicator variables, to make water quality predictions for water downstream of the discharge point. Both of these variables are readily available and supply a workable degree of estimate precision. Appendix A presents the development and application of the regression models.

Under Mining Alternatives 1 or 2, Mesabi Nugget intends to install the following to ensure compliance with water quality standards in the St, Louis River:

1) Continuous specific conductance monitoring stations in the pits from which water is pumped to permitted receiving waters,

2) A continuous specific conductance monitoring and stream gauging station in the St. Louis River (located downstream of the confluence of the Partridge River (Figure 1)), and

3) A diffuser at its discharge point to facilitate complete mixing of the effluent with the St. Louis River.

Water will be pumped from the pits at a rate based on the measured flow rate and specific conductance in the St. Louis River. This hydrograph-controlled discharge approach (Appendix A) will ensure that water quality standards are met in the St. Louis River. The ratio of discharges of water from the Project pits to the stream flow will then be set to ensure that water quality standards are met at the edge of the mixing zone. (The exception to this will be mercury and acute toxicity standards, which will be met at the discharge point.)

## 3.5 Mitigation

Mesabi Mining will initiate mitigation efforts to reduce loading of sulfate and other dissolved constituents and improve water quality of the pit discharge, in conjunction with mining at the project site. These efforts include improved soil covers on four legacy lower slaty stockpiles and/or placing those legacy stockpiles subaqueous in Area 1 or Area 6 Pits. These mitigation efforts may impact the water management plans and the pit water balances. Mesabi Mining may alter its water management plans to ensure that water quality standards will be met at the regulatory compliance point (e.g. edge of the mixing zone).

# 4.0 Water Management Plan for Mining Alternative 1

This section provides the results of the simulation of the water management plan for Mining Alternative 1. The calculated dewatering times and the maximum accumulated volume in the pits are presented. An overview of the water management of each pit is also presented. Refer to the Mine Pit Hydrogeology and Water Balances report (Barr, 2011b) and Dissolved Solids and Chemical Balance report (Barr, 2011d) for additional details of the water and chemical balances of each pit.

## 4.1 Dewatering Times

The initial dewatering times for the Area 2WX Pit and Area 6 Pit under Mining Alternative 1, based on meeting water quality standards at the edge of the mixing zone are presented in Table 4-1. The maximum, minimum, and average dewatering times (which vary according to the flow in the St. Louis River) are presented.

**Table 4-1 Estimated Mine Pit Initial Dewatering Times**

| Condition (based on flow record) | Alternative 1 Dewatering Time (years) | | |
|---|---|---|---|
| | Area 1 Pit | Area 6 Pit | Area 2WX Pit |
| Minimum | -- | 3.5 | 1.3 |
| Average | -- | 5.4 | 2.1 |
| Maximum | -- | 7.7 | 3.1 |

Although there is some variability in dewatering times due to the variability in St. Louis River flows, the range of estimated dewatering times for the Area 2WX Pit is limited to 1.3 to 3.1 years for Alternative 1. The range of estimated dewatering times for the Area 6 Pit is 3.5 to 7.7 years for Alternative 1. In all modeled cases, the Area 2WX Pit was dewatered within 3.1 years and the Area 6 Pit was dewatered within 7.7 years. The dewatering of the pits for minimum, maximum, and average cases are presented as time series in Figure 4 for the Area 6 Pit and in Figure 5 for the Area 2WX Pit.

## 4.2 Accumulated Volume in the Pits

Following the initial dewatering of the Area 2WX Pit, water accumulates in the Area 1 Pit and Area 6 Pit when there is insufficient assimilative capacity in the river to accommodate all maintenance dewatering. Water entering the Area 2WX Pit that cannot be dewatered to the St. Louis

River is routed to the Area 6 Pit to allow uninterrupted mining operations in the Area 2WX Pit. Mining may be disrupted in the Area 6 Pit, or moved to higher benches in the mine pit.

The maximum amount of storage necessary for each pit varies according to the allowable discharge to the St. Louis River. The approximate maximum storage volumes occurring within the expected 20 year life of the project were calculated using each year from 1942 to 1980 in the St. Louis River flow record as the starting year. The resulting maximum, minimum, and average values are presented in Table 4-2. The accumulated storage in the Area 6 Pit is presented in Figure 4 (note that the average case is illustrated by a single representative time series, and thus does not match the average value exactly). The volume of water in the Area 2WX Pit is shown in Figure 5 and accounts for the transfer of excess water to the Area 6 Pit following initial dewatering. This analysis assumes that the Area 6 Pit is dewatered to prevent seepage to Second Creek. In both mining alternatives, this requires dimpling the Area 6 Pit below its subsurface outflow elevation (1450 ft) to allow for increasing water levels in the pit when Area 2WX Pit water is pumped to Area 6 Pit. The required dimpling volume and elevation necessary in the Area 6 Pit is summarized in Table 4-3, again as maximum, minimum, and average values based on variability in St. Louis River flows. The maximum storage required in the Area 6 Pit and Area 1 Pit decreases as the allowable constituent concentrations in the St. Louis River increase. The accumulation of water in the Area 1 Pit is similar for Mining Alternatives 1 and 2 and is presented in Figure 6.

The potential accumulation of water within the mine pits following initial dewatering is not insignificant. In the Area 1 Pit, 1,000 acre-feet of water corresponds to a 2-foot increase in surface water elevation. In the Area 6 Pit, the maximum volumes presented in Table 4-2 correspond to a depth of 113 feet and an area of 143 acres for Mining Alternative 1 (based on pre-mining bathymetry).

**Table 4-2 Estimated Maximum Accumulation Following Initial Pit Dewatering**

| Condition (based on flow record) | Maximum estimated accumulation (acre-feet) | | |
|---|---|---|---|
| | Mining Alternative 1 | | |
| | Area 1 Pit | Area 6 Pit | Area 2WX Pit |
| Minimum | 0 | 1,000 | 0 |
| Average | 520 | 2,200 | 0 |
| Maximum | 1,000 | 6,600 | 0 |

**Table 4-3 Estimated Storage Requirements in Area 6 Pit to Prevent Outflow to Second Creek**

| Condition (based on flow record) | Mining Alternative 1 (during dewatering of Area 2WX Pit) | |
|---|---|---|
| | Area 6 Pit Max. Volume (acre-ft) | Area 6 Pit Max. Elevation (ft) |
| Minimum | 27,000 | 1432 |
| Average | 29,900 | 1442 |
| Maximum | 30,500 | 1444 |

## 4.3 Pit Water Management Overview

Figure 5 illustrates the water management plan for Mining Alternative 1. Under Mining Alternative 1, water management at each of the pits will be as follows:

- The Area 2WX Pit will be dewatered during the first 1.3 to 3.1 years to the St. Louis River, after which time mining will commence. After the pit has been dewatered, maintenance dewatering will be required to keep the pit dry. Dewatering will cease at the conclusion of operations and the pit will be allowed to refill. Final elevation will be chosen to prevent subsurface outflow, and water will be pumped to the St. Louis River in closure.
- The Area 6 Pit will also be dewatered for 3.5 to 7.7 years to the St. Louis River, after which time mining will commence. After the pit has been dewatered, maintenance dewatering will be required to keep the pit dry. Dewatering will cease at the conclusion of operations and the pit will be allowed to refill to an elevation of 1445 ft. Maintenance dewatering will then continue to the St. Louis River in closure to maintain the elevation below 1450 ft.
- The Phase I LSDP will operate for the entire mining period (from Year 0 through Year 20), using the Area 1 Pit as water supply and as water treatment. Concentrate will be produced from ore on site, and the resultant tailings will be deposited in the west end of Area 1 Pit, per the Tailing Basin Concept Design report (Barr, 2011j and Barr, 2009i). During operations, the Area 1 Pit Clear Water Pool will be maintained at a water level of 1541.7 ft when possible, and below 1545.2 ft at all times, by pumping to the St. Louis River. During closure, the Area 1 Pit Clear Water Pool will be allowed to fill to an elevation of 1544 ft to provide 2 ft of buffer capacity below the seep by pumping to the St. Louis River.
- An initial drawdown of the Area 9 Pit water level will be required to implement the subaqueous material placement strategy. This water will be pumped to the Area 1 Pit. Maintenance dewatering of the Area 9 Pit will also be directed to the Area 1 Pit to maintain

the water level at 1545 ft. After closure, the pit will be allowed to refill to its natural elevation of 1548 ft.

- Mining will begin in the Area 6NW Pit. Water collected in the new pit will be dewatered to the Area 6 Pit through operations, and the pit will merge with Area 6 Pit in closure.

No variances are required under this alternative because water quality standards will be met at the edge of the mixing zone in the St. Louis River. The hydrograph-controlled discharge approach will ensure that water quality standards are met at the regulatory compliance point and that aquatic life and other uses are protected. The discharge rates will be set based on flow rates of the St. Louis River and on water quality of both the discharge and the St. Louis River as determined from continuous specific conductance readings at the pit and the St. Louis River. Mercury and acute toxicity will be met at the discharge point.

No water will be transferred to or from Stephens, Knox or the Area 9S Pits under Mining Alternative 1.

## 4.4 Legacy Mitigation

Pumping water from the Area 1, 2WX and 6 Pits to the St. Louis River will improve the water quality in Second Creek and the Partridge River, while continuing to meet water quality standards in the St. Louis River. However, flow in Second Creek will be reduced as flows from these pits are rerouted to the St. Louis River. Flows will return to those similar, although somewhat lower than pre-mining flows. While the watersheds of the pits will be removed from the Second Creek watershed, these watersheds are relatively small part of the overall watershed of Second Creek.

Improved capping and/or subaqueous disposal of lower slaty waste rock piles 1054, 6011, 6014 and 6015 will directionally reduce the sulfate and dissolved solids loadings to Area 1 and Area 6 Pits. The extent of reduction will be determined by the ultimate method of mitigation and the efficacy of those mitigation methods.

# 5.0 Water Management Plan for Mining Alternative 2

This section provides the results of the simulation of the water management plan for Mining Alternative 2. The calculated dewatering times and the maximum accumulated volume in the pits are presented. An overview of the water management of each pit is also presented. Refer to the Mine Pit Hydrogeology and Water Balances report (Barr, 2011b) and Dissolved Solids and Chemical Balance report (Barr, 2011d) for additional details of the water and chemical balances of each pit.

## 5.1 Dewatering Times

The initial dewatering times for the Area 2WX Pit under Mining Alternative 2 are based on the acceptable constituent concentration in the mixing zone and are presented in Table 5-1. The maximum, minimum, and average dewatering times (which vary according to the flow in the St. Louis River) are presented.

**Table 5-1 Estimated Mine Pit Initial Dewatering Times**

| Condition (based on flow record) | Alternative 1 Dewatering Time (years) | | |
|---|---|---|---|
| | Area 1 Pit | Area 6 Pit | Area 2WX Pit |
| Minimum | -- | -- | 1.5 |
| Average | -- | -- | 2.5 |
| Maximum | -- | -- | 3.7 |

It takes slightly longer to dewater the Area 2WX Pit under Mining Alternative 2 than under Mining Alternative 1. This is because the continued dewatering of the Area 6 Pit under Mining Alternative 1 creates additional bounce in the Area 6 Pit below the dimple elevation; during periods of low flow, this extra bounce allows the Area 6 Pit to accumulate water that does not have to be dewatered ahead of the Area 2WX Pit because it is below the dimpling elevation.

Although there is some variability in dewatering times due to the variability in St. Louis River flows, the range of estimated dewatering times for the Area 2WX Pit is 1.5 to 3.7 years for Alternative 2. In all modeled cases, however, the Area 2WX Pit was dewatered within 3.7 years. The dewatering of the pits for minimum, maximum, and average cases are presented as time series in Figure 8 for the Area 2WX Pit.

## 5.2 Accumulated Volume in the Pits

Following the initial dewatering of the Area 2WX Pit, water accumulates in the Area 1 Pit and Area 6 Pit when there is insufficient assimilative capacity in the river to accomplish all maintenance dewatering. Water entering the Area 2WX Pit that cannot be dewatered to the St. Louis River is routed to the Area 6 Pit to allow uninterrupted mining operations in the Area 2WX Pit.

The maximum amount of storage necessary for each pit varies according the allowable discharge to the St. Louis River. The approximate maximum storage volumes occurring within the expected 20 year life of the project were calculated using each year from 1942 to 1980 in the St. Louis River flow record as the starting year. The resulting maximum, minimum, and average values are presented in Table 5-2. The volume of water in the Area 2WX Pit is shown in Figure 8 and accounts for the transfer of excess water to the Area 6 Pit following initial dewatering. This analysis assumes that the Area 6 Pit is dewatered to prevent seepage to Second Creek. In both mining alternatives, this requires dimpling the Area 6 Pit below its outflow elevation (1450 ft) to allow some bounce in the pit. The required dimpling volume and elevation necessary in the Area 6 Pit is summarized in Table 5-3, again as maximum, minimum, and average values based on variability in St. Louis River flows. The maximum storage required in the Area 6 Pit and Area 1 Pit decreases as the allowable constituent concentrations in the St. Louis River increase. The accumulation of water in the Area 1 Pit is similar for Mining Alternatives 1 and 2 and is presented in Figure 6.

The potential accumulation of water within the mine pits following initial dewatering is not insignificant. In the Area 1 Pit, 1,000 acre-feet of water corresponds to a 2-foot bounce in water surface.

**Table 5-2 Estimated Maximum Accumulation Following Initial Pit Dewatering**

| Condition (based on flow record) | Maximum estimated accumulation (acre-feet) | | |
|---|---|---|---|
| | Mining Alternative 1 | | |
| | Area 1 Pit | Area 6 Pit | Area 2WX Pit |
| Minimum | 0 | 0 | -- |
| Average | 520 | 0 | -- |
| Maximum | 1,000 | 0 | -- |

**Table 5-3 Estimated Storage Requirements in Area 6 Pit to Prevent Outflow to Second Creek**

| Condition (based on flow record) | Mining Alternative 1 (during dewatering of Area 2WX Pit) | |
|---|---|---|
| | Area 6 Pit Max. Volume (acre-ft) | Area 6 Pit Max. Elevation (ft) |
| Minimum | 25,000 | 1426 |
| Average | 27,500 | 1434 |
| Maximum | 29,500 | 1441 |

## 5.3 Pit Water Management Overview

Figure 9 illustrates the water management plan for Mining Alternative 2. Under Mining Alternative 2, water management at each of the pits will be as follows:

- The Area 2WX Pit will be dewatered during the first 1.5 to 3.7 years to the St. Louis River, after which time mining will commence. After the pit has been dewatered, maintenance dewatering will be required to keep the pit dry. Final elevation will be chosen to prevent subsurface outflow, and water will be pumped to the St. Louis River in closure.
- The Area 6 Pit will also be dewatered to the St. Louis River to an elevation of 1434 ft. Dewatering will continue to maintain the pit below an elevation of 1450 ft to prevent subsurface outflow. At the conclusion of operations, the pit will be allowed to refill to an elevation of 1445 ft. Maintenance dewatering will then continue to the St. Louis River to maintain the elevation below 1450 ft. .
- The Phase I LSDP will operate for the entire mining period (from Year 0 through Year 20), using the Area 1 Pit as water supply and as water treatment. Concentrate will be produced from ore on site, and the resultant tailings will be deposited in the west end of Area 1 Pit, per the Tailing Basin Concept Design report (Barr, 2011j and Barr, 2009i). During operations, the Area 1 Pit Clear Water Pool will be maintained at a water level of 1541.7 ft when possible, and below 1545.2 ft at all times, by pumping to the St. Louis River. In closure, the Area 1 Pit Clear Water Pool will be allowed to fill to an elevation of 1544 ft to provide 2 ft of buffer capacity below the seep. That elevation will be maintained by pumping to the St. Louis River in closure.
- An initial drawdown of the Area 9 Pit water level will be required to implement the subaqueous material placement strategy. This water will be pumped to the Area 1 Pit. Maintenance dewatering of the Area 9 Pit will also be directed to the Area 1 Pit to maintain

the water level at 1545 ft. After Year 10 when mining in the Area 6NW Pit has been completed, the pit will be allowed to refill to its natural elevation of 1548 ft.

- Mining will occur in the Area 6NW Pit during the first 10 years of operations. Water collected in the new pit will be dewatered to the Area 6 Pit through operations. The pit will be allowed to refill to its natural elevation of 1535 ft following closure.

No variances are required under this alternative because water quality standards will be met at the regulatory compliance points in the St. Louis River. The hydrograph-controlled discharge approach will ensure that water quality standards are met at the end of the regulatory mixing zone. The discharge rates will be set based on water quality of both the discharge and the St. Louis River as determined from continuous specific conductance readings at the pit and the St. Louis River. Mercury and acute toxicity will be met at the discharge point.

No water will be transferred to or from Stephens, Knox or the Area 9S Pits under Mining Alternative 2.

## 5.4 Legacy Mitigation

Pumping water from the Area 1, 2WX and 6 Pits to the St. Louis River will improve the water quality in Second Creek and the Partridge River, while continuing to meet water quality standards in the St. Louis River. However, flow in Second Creek will be reduced as flows from these pits are rerouted to the St. Louis River. Flows will return to those similar, although somewhat lower than pre-mining flows. While the watersheds of the pits will be removed from the Second Creek watershed, these watersheds are relatively small part of the overall watershed of Second Creek.

Improved capping and/or subaqueous disposal of lower slaty waste rock piles 1054, 6011, 6014 and 6015 will directionally reduce the sulfate and dissolved solids loadings to Area 1 and Area 6 Pits. The exact extent of reduction will be determined by the ultimate method of mitigation and the efficacy of those mitigation methods.

# 6.0 Water Management Plan for the No Action Alternative

This section provides an overview of the water management of each pit. Refer to the Mine Pit Hydrogeology and Water Balances report (Barr, 2011b) and Dissolved Solids and Chemical Balance report (Barr, 2011d) for additional details of the water and chemical balances of each pit.

Figure 10 illustrates the water management plan for the No Action Alternative. Under the No Action Alternative, no mining will occur; however, the Phase I LSDP will operate, using the Area 1 Pit as a water supply and as water treatment (Barr, 2011b). If this alternative is chosen, nondegradation analyses will be completed as necessary for submittal as part of the NPDES permit application process. Discharges from the Area 1, Area 2WX, and Area 6 Pits would require these analyses. Under the No Action Alternative, water management at each of the pits will be as follows.

## 6.1 Area 1 Pit

The Area 1 Pit is currently pumped to Second Creek to provide 6 months to 3 years of storage within the pit; it will continue to be pumped to Second Creek throughout operation of the LSDP. The discharge will comply with the NPDES permit issued to Mesabi Nugget. During Closure, discharge by pumping or by a surface outlet constructed at an elevation of 1546 ft will continue to Second Creek. Variances will be necessary for the Area 1 Pit discharge under this alternative. Variance applications for total dissolved solids, alkalinity, hardness, sulfate and specific conductance will be submitted as part of the NPDES permit application.

## 6.2 Area 2WX Pit

The Area 2WX Pit will not be mined and will continue to refill, similar to present conditions. The pit is predicted to overflow to Unnamed Creek during Year 3. The water will flow from the Area 2WX Pit via an existing, remnant surface water channel as described in the East Range Hydrology Study (Adams et al., 2004). Variances will be necessary for the Area 2WX discharge under this alternative. Variance applications for bicarbonate and sulfate (wild rice) will be submitted as part of the NPDES permit application.

## 6.3 Area 6 Pit

The Area 6 Pit currently overflows through adjacent unconsolidated deposits to Second Creek and will continue to do so under the No Action Alternative. Variances will be necessary for the Area 6

Pit discharge under this alternative. Variance applications for TDS, alkalinity, hardness, sulfate and specific conductance will be submitted as part of the NPDES application.

## 6.4 Area 9 Pit

The Area 9 Pit will be allowed to continue to overflow to the Area 1 Pit to the north and to the south. No management or transfer of water into or out of the Area 9 Pit will occur under this alternative.

# 7.0 Summary

This report documents the proposed water management plans that generally explain where water will be transferred during the Mesabi Nugget Phase II Project under the two mining alternatives and the No Action Alternative. The water management plans presented in this report are designed to manage the transfer of water during Project operations. Water quality and quantity impacts to receiving waters were considered during the development of the water management plans; however, those impacts are not presented or discussed in this report.

The existing NPDES water discharge permits allow discharges to Second Creek and Unnamed Creek, which both flow into the St. Louis River via the Partridge River. Under Mining Alternatives 1 and 2, the permit applications will request that those outfalls to be moved to a single outfall point, allowing Mesabi Nugget to discharge water from the Area 1 Pit, and Mesabi Mining to discharge water from Area 6 Pit, and Area 2WX Pit to the St. Louis River. By doing this, discharges from the Project will comply with applicable water quality criteria without the need for water treatment or variances.

The estimated pumping rates and drawdown estimates presented in the water management plans (for Mining Alternative 1, Mining Alternative 2, and the No Action Alternative presented in Sections 4.0, 5.0, and 6.0, respectively) are based on initial estimates of pumping and drawdown calculated in the future conditions water balances. The water quality impacts of these initial estimates were subsequently assessed by inputting the rates into chemical balances, which predicted the future chemistry of the pits. Finally, the water quality impacts in the St. Louis River will be assessed combining the existing St. Louis River water quality and the predicted water quality of the Project pit discharges in a simple water- and mass-balance model.

A linear regression model between the expected limiting water quality parameters and specific conductance has been developed that can be used to control discharge rates from the Project pits to the St. Louis River. Mesabi Mining will install continuous specific conductance monitoring stations in the Project pits, a continuous flow monitoring station in the St. Louis River, and a diffuser at the discharge location to ensure that the water quality standards are met at the end of a regulatory mixing zone (or at the discharge point, as needed).

Legacy mitigation, including pumping to the St. Louis River as part of the project, will improve the water quality in Second Creek and the Partridge River, while continuing to meet water quality standards in the St. Louis River. However, flow in Second Creek will be reduced as flows from these pits are rerouted to the St. Louis River. Flows will return to those similar, although somewhat lower than pre-mining flows. While the watersheds of the pits will be removed from the Second Creek watershed, these watersheds are relatively small part of the overall watershed of Second Creek.

# 8.0 References

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Barr Engineering Company, 2011h. *Area 1 Pit Water Treatment Evaluation in Support of the Nondegradation Analysis - Mesabi Nugget Phase II*. (Draft-02 to be submitted 2011).

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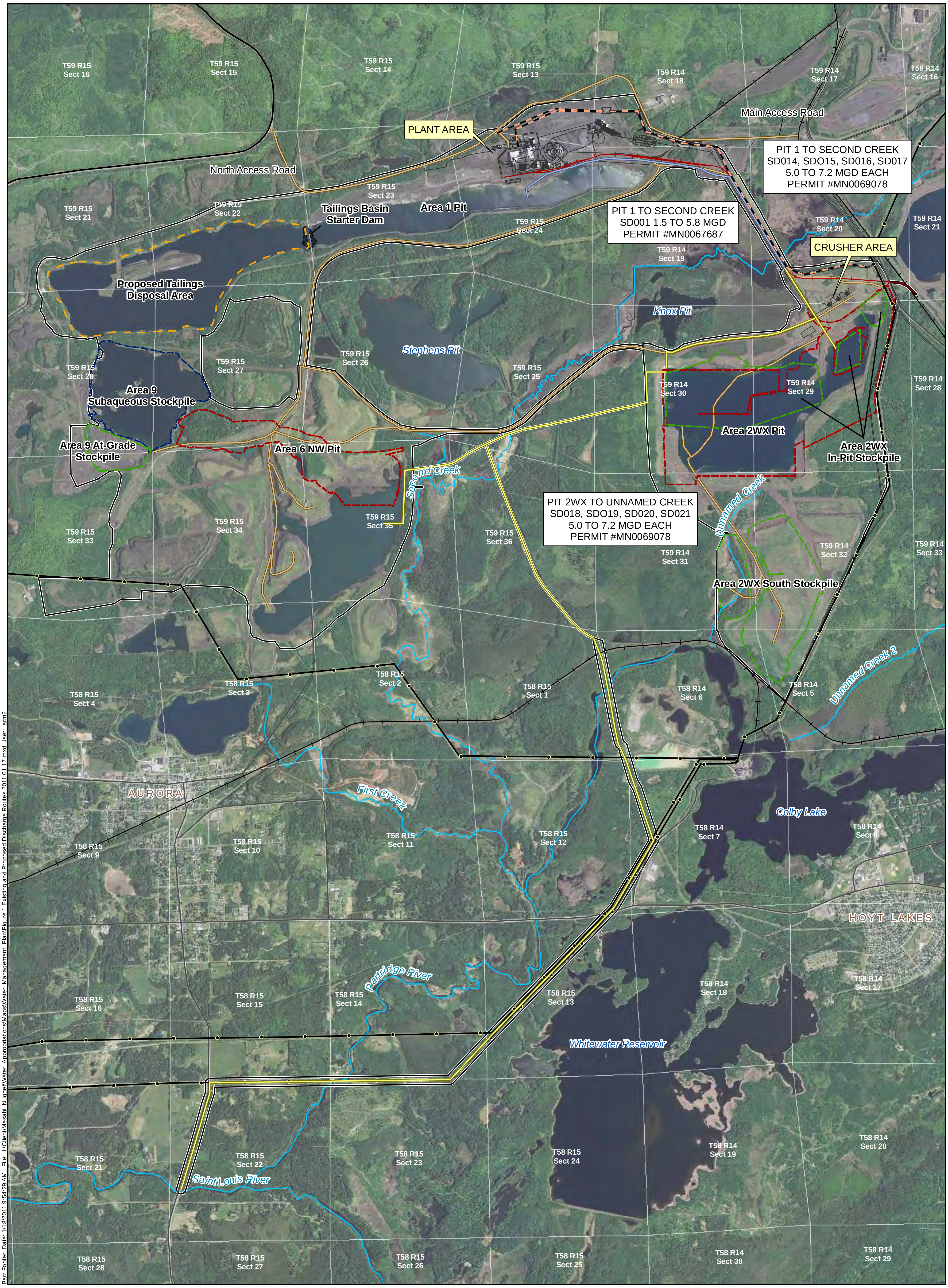
MPCA, 2005. *MPCA NPDES/SDS Permit #MN0067687 for Mesabi Nugget Delaware LLC and Steel Dynamics, Inc.* July 2005.

MPCA, 2007. *MPCA NPDES/SDS Permit # MN0069078 for Mesabi Mining, LLC and Steel Dynamics, Inc.* November 2007.

# Figures






Project Boundary
Proposed Mine Pit Footprints (Period 8)
Proposed Stockpile Footprints (Period 8)
Proposed Stockpile Footprint (Period 8)
Subaqueous Stockpile (Period 8)
Tailings Disposal Area
Proposed Pipeline Route
Haul Roads
Water Line
Existing Transmission Line
Proposed Transmission Line
Plant Site Railroads
Plant Layout
Rivers & Streams

3,000 1,500 0 3,000
Feet

Figure 1
EXISTING AND PROPOSED
DISCHARGE ROUTES
Mesabi Nugget Phase II
Hoyt Lakes, Minnesota

**Figure 2.** Comparison of IC25 of Area 6 Pit Water with Predicted Discharge Rate to St. Louis River during Alternative 1

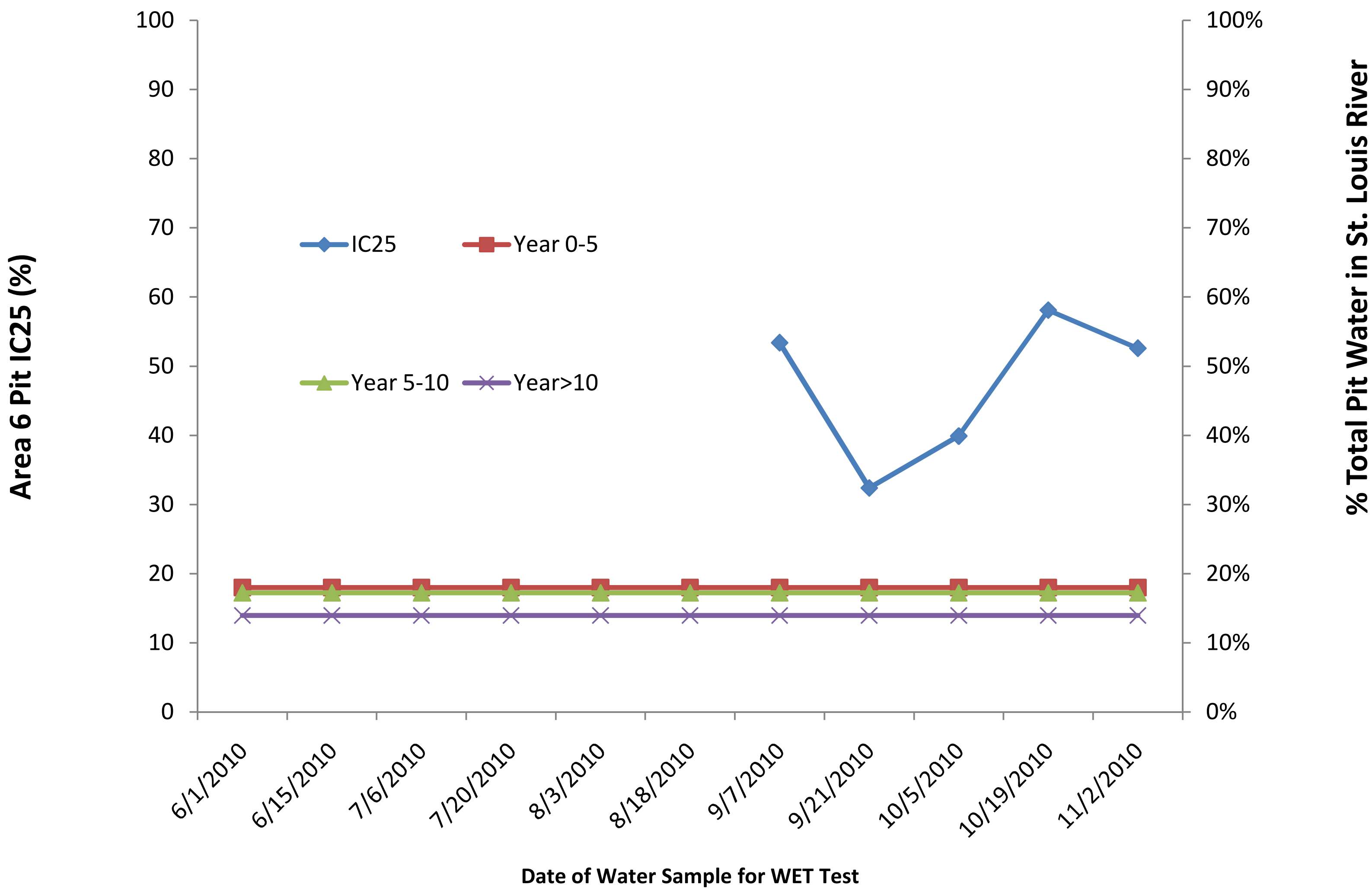
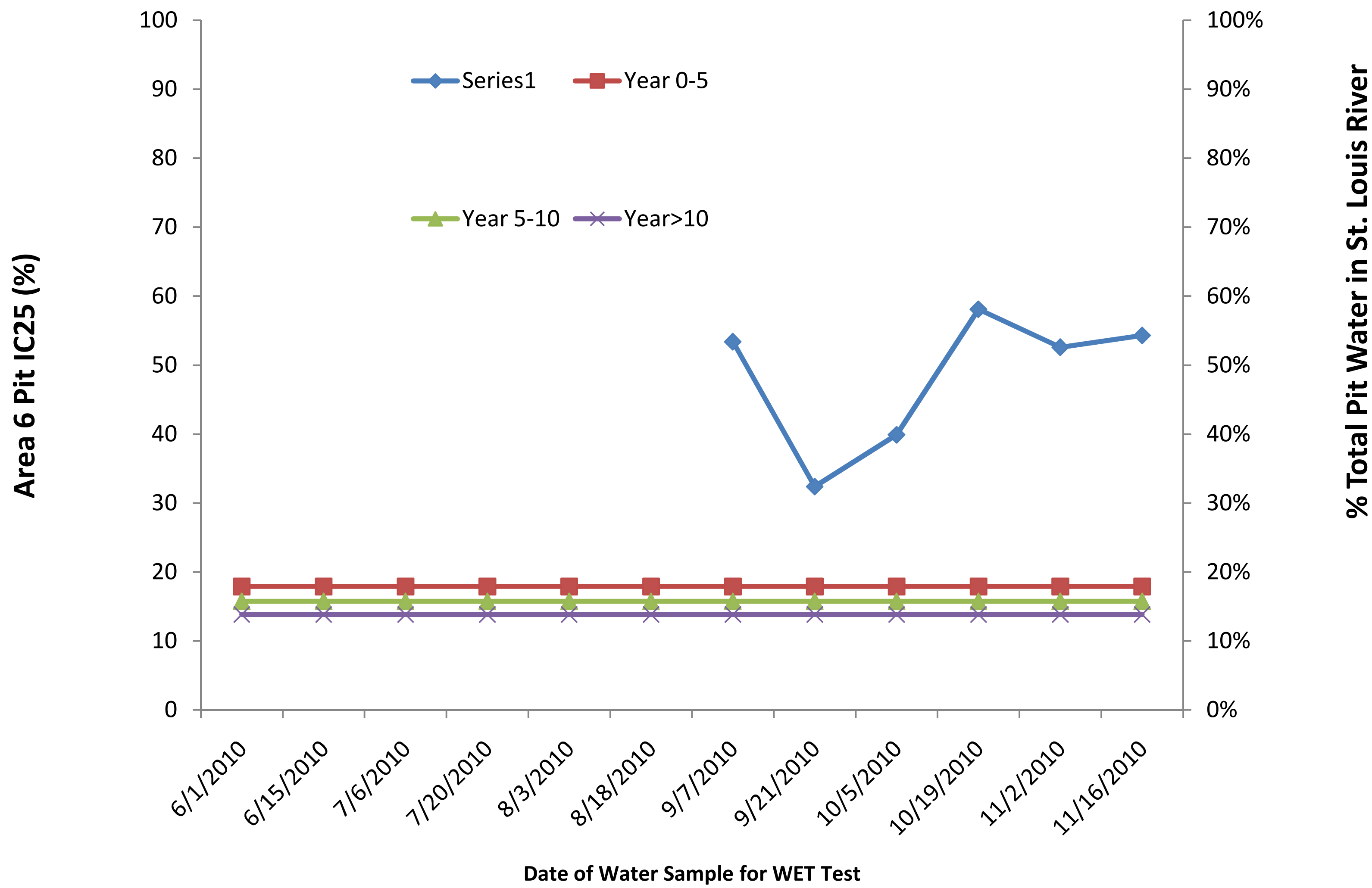


**Figure 3.** Comparison of IC25 of Area 6 Pit Water with Predicted Discharge Rate to St. Louis River during Alternative 2



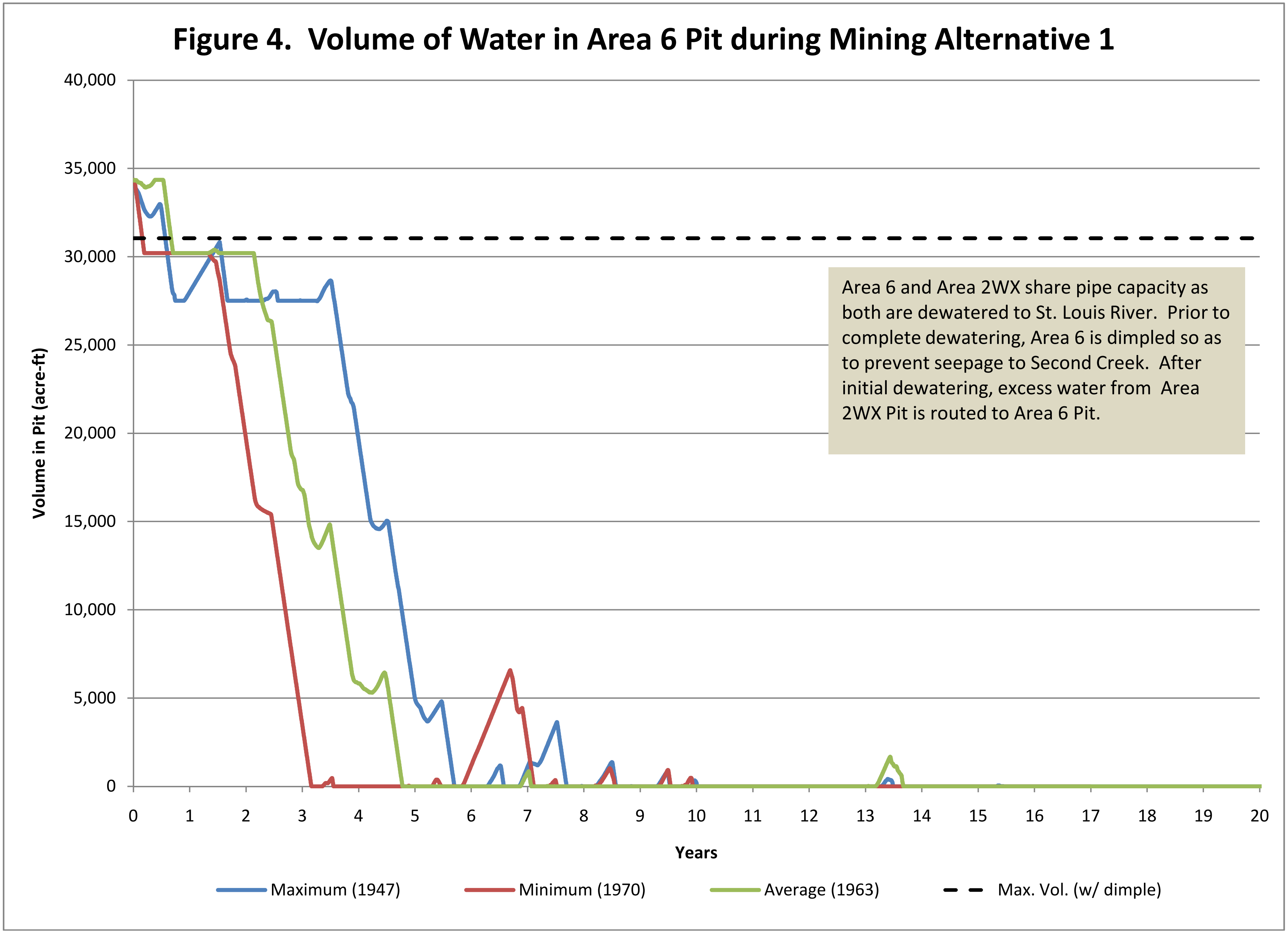


Figure 4. Volume of Water in Area 6 Pit during Mining Alternative 1
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume in Pit (acre-ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Years
Area 6 and Area 2WX share pipe capacity as both are dewatered to St. Louis River. Prior to complete dewatering, Area 6 is dimpled so as to prevent seepage to Second Creek. After initial dewatering, excess water from Area 2WX Pit is routed to Area 6 Pit.
Maximum (1947)
Minimum (1970)
Average (1963)
Max. Vol. (w/ dimple)

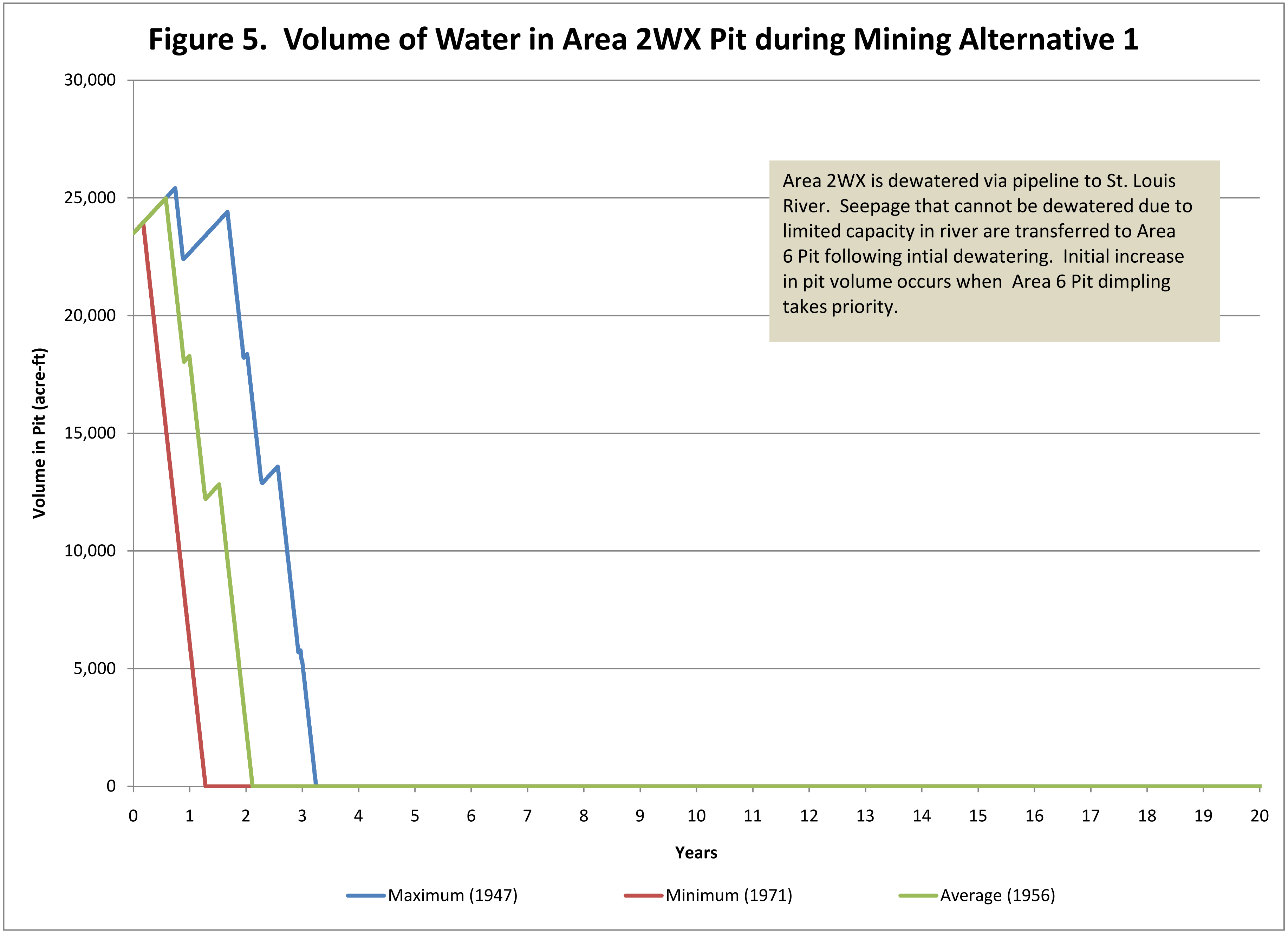


Figure 5. Volume of Water in Area 2WX Pit during Mining Alternative 1
30,000
25,000
20,000
15,000
10,000
5,000
0
Volume in Pit (acre-ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Years
Area 2WX is dewatered via pipeline to St. Louis River. Seepage that cannot be dewatered due to limited capacity in river are transferred to Area 6 Pit following intial dewatering. Initial increase in pit volume occurs when Area 6 Pit dimpling takes priority.
Maximum (1947)
Minimum (1971)
Average (1956)

# Figure 6. Volume of Excess Water In Area 1 Pit during Mining Alternatives 1 and 2

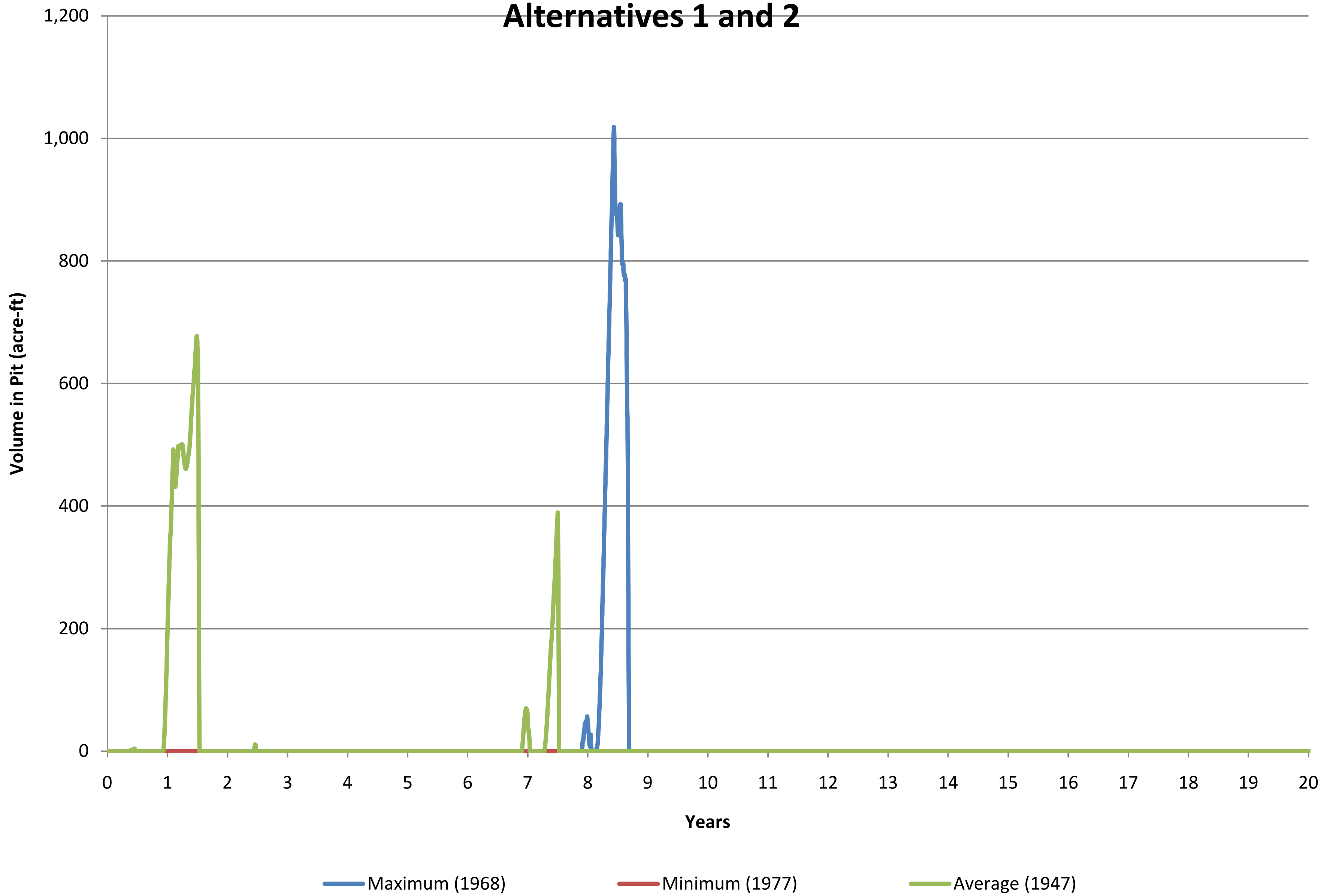


Figure 7a. Years 0 - 10

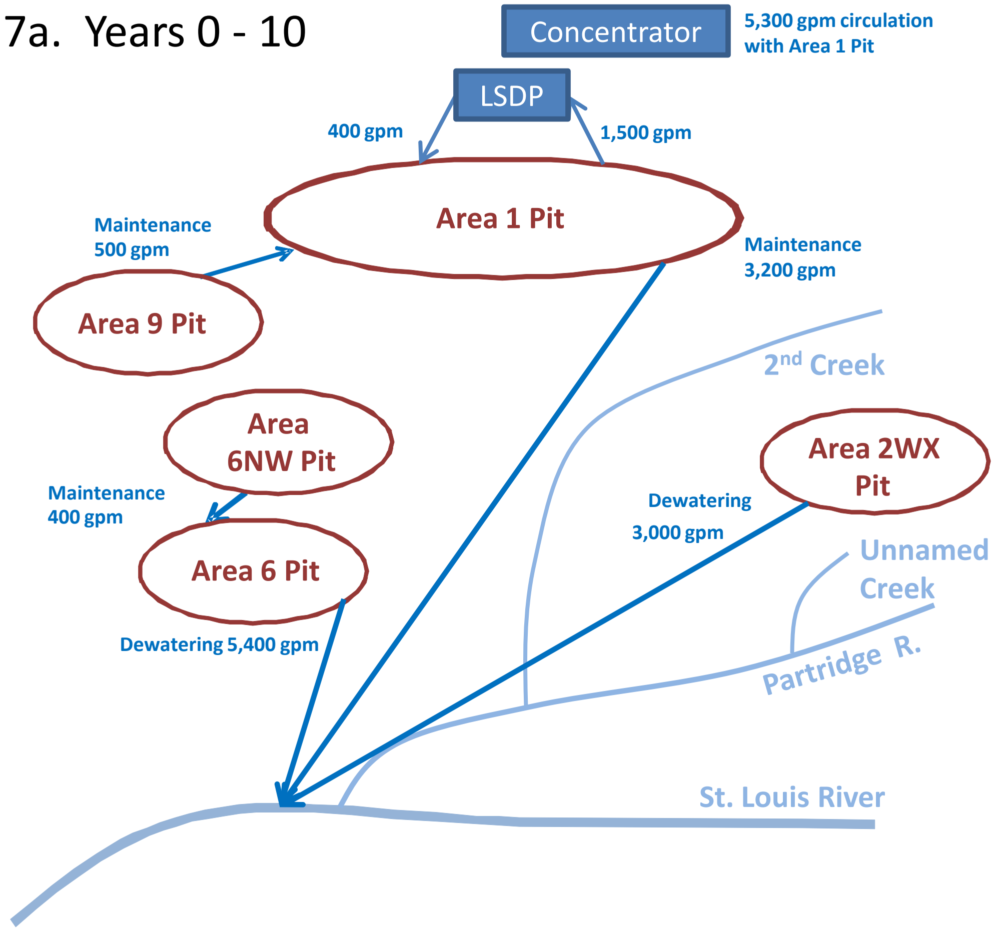



Figure 7b. Years 11 - 20

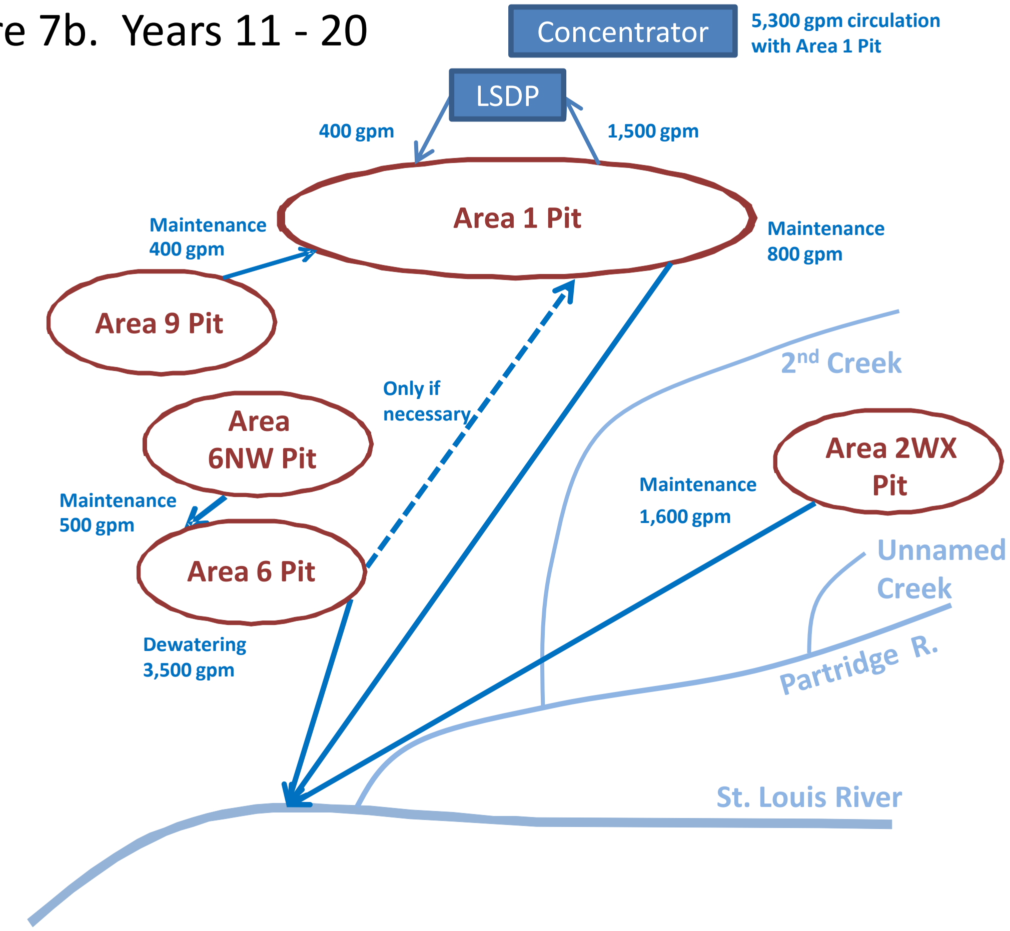
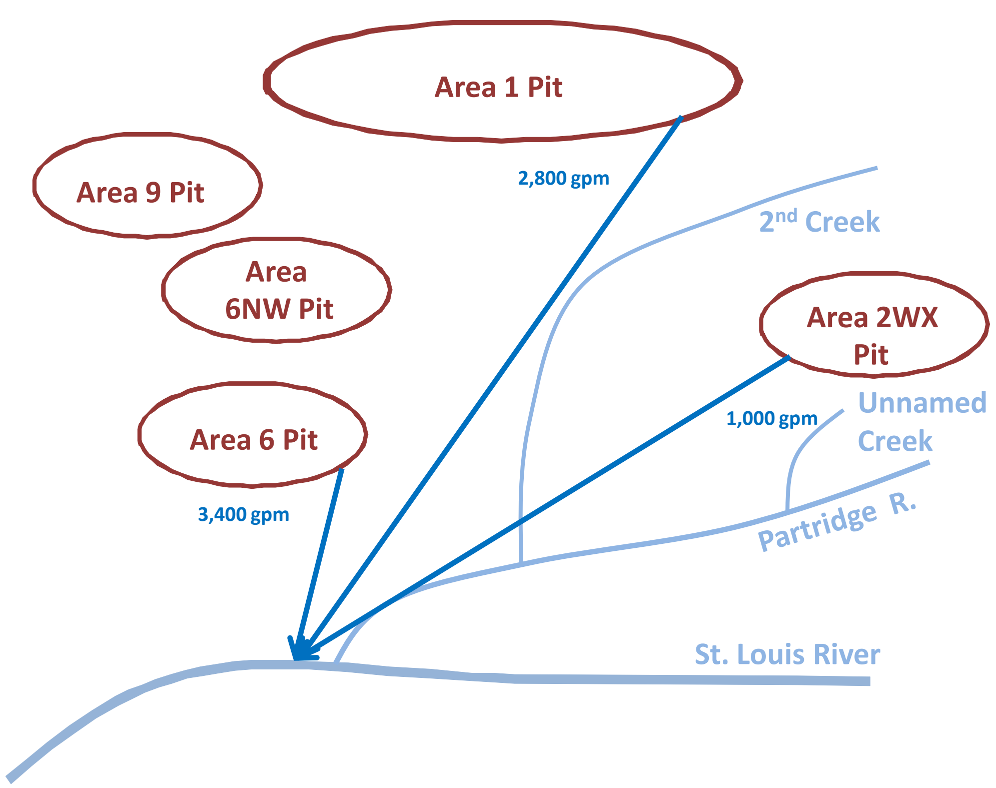



Figure 7c. Closure




Expected pumped water movement, as reflected in water balances

Alternative flow path for water movement

Passive water movement

*Assumes that a pipeline is constructed to the St. Louis River in Year 0. Only pits that are part of the Phase II Project are shown. Average annual flow rates are rounded to the nearest 100 gallons per minute (gpm). Seasonal variation is expected.*

Figures 7a – 7c

PROCESS WATER MANAGEMENT PLAN
FLOW FIGURES FOR
MINING ALTERNATIVE 1
Mesabi Nugget Phase II
Hoyt Lakes, Minnesota

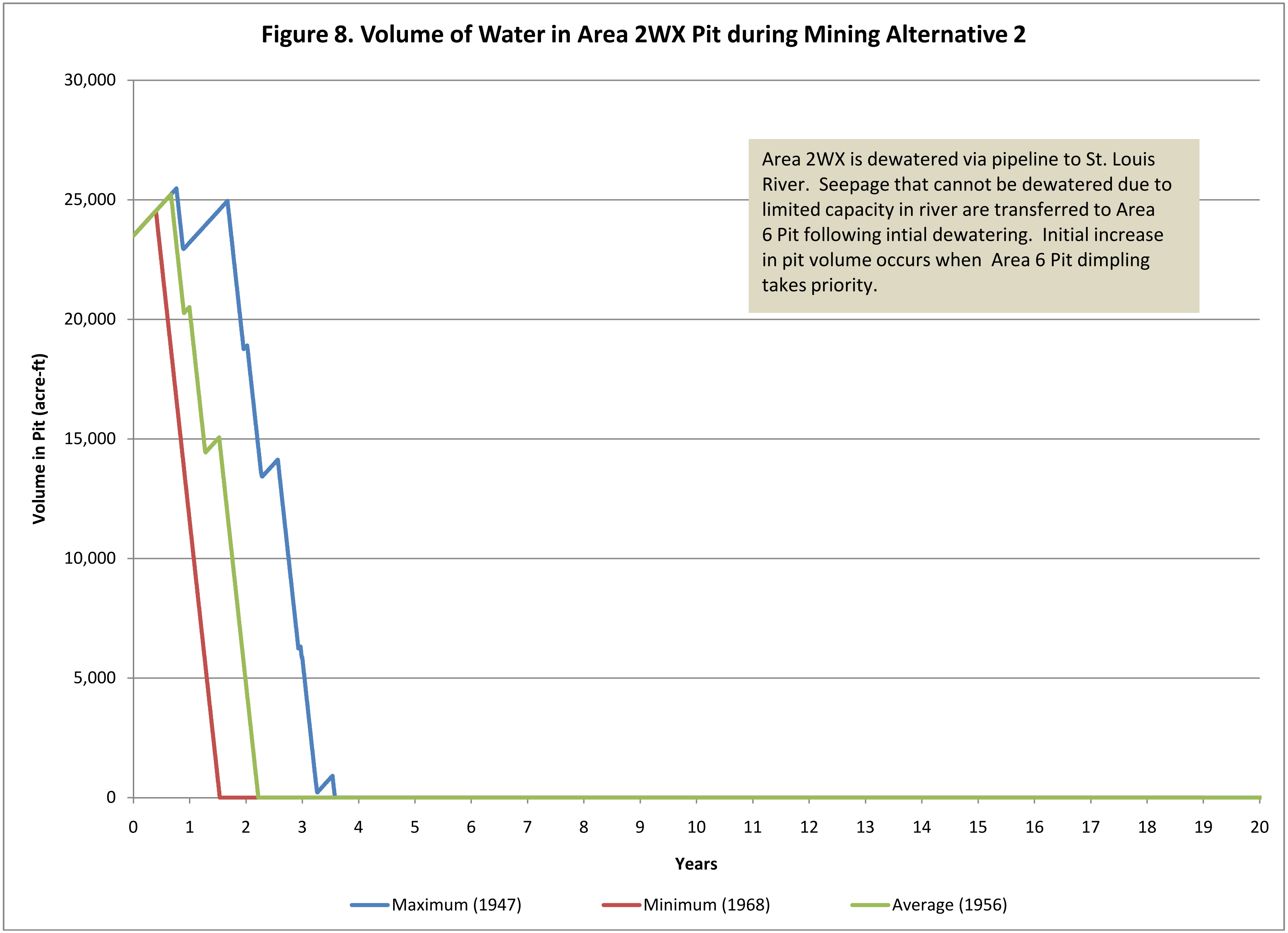


Figure 8. Volume of Water in Area 2WX Pit during Mining Alternative 2
Area 2WX is dewatered via pipeline to St. Louis River. Seepage that cannot be dewatered due to limited capacity in river are transferred to Area 6 Pit following intial dewatering. Initial increase in pit volume occurs when Area 6 Pit dimpling takes priority.
Volume in Pit (acre-ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Years
Maximum (1947)
Minimum (1968)
Average (1956)

Figure 9a. Years 0 - 10

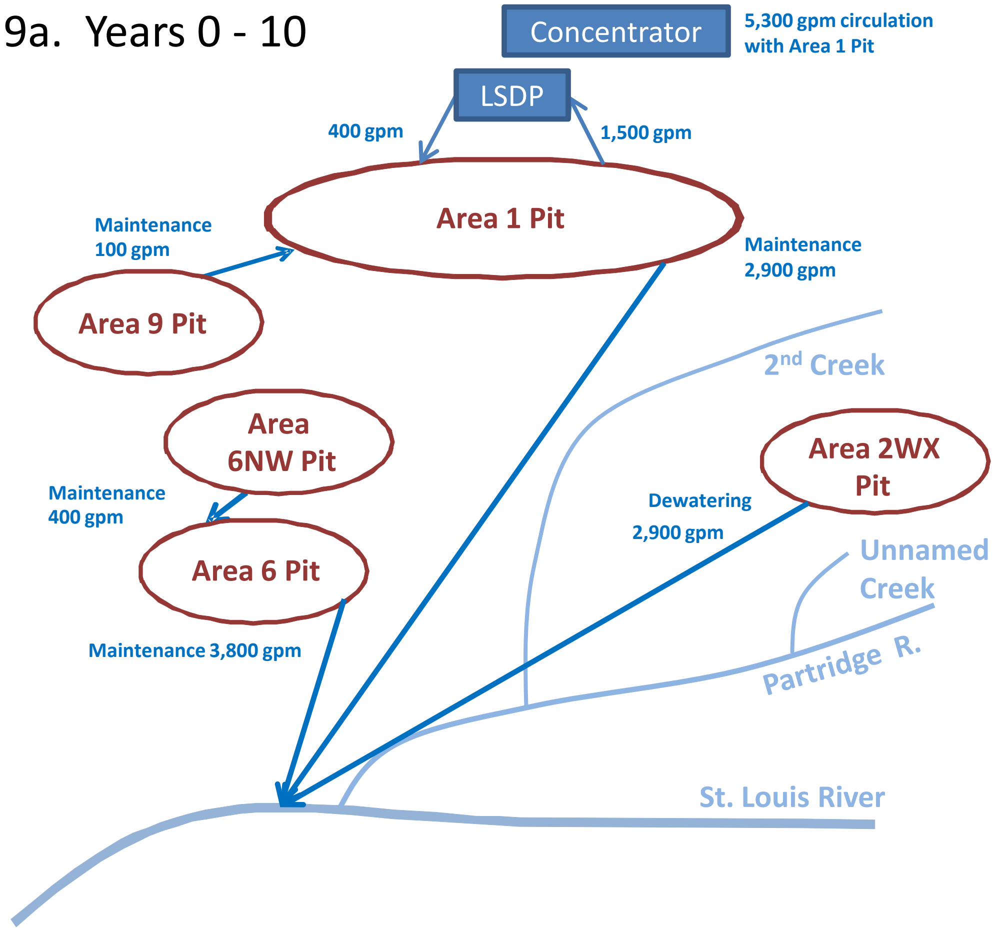



Figure 9b. Years 11 - 20

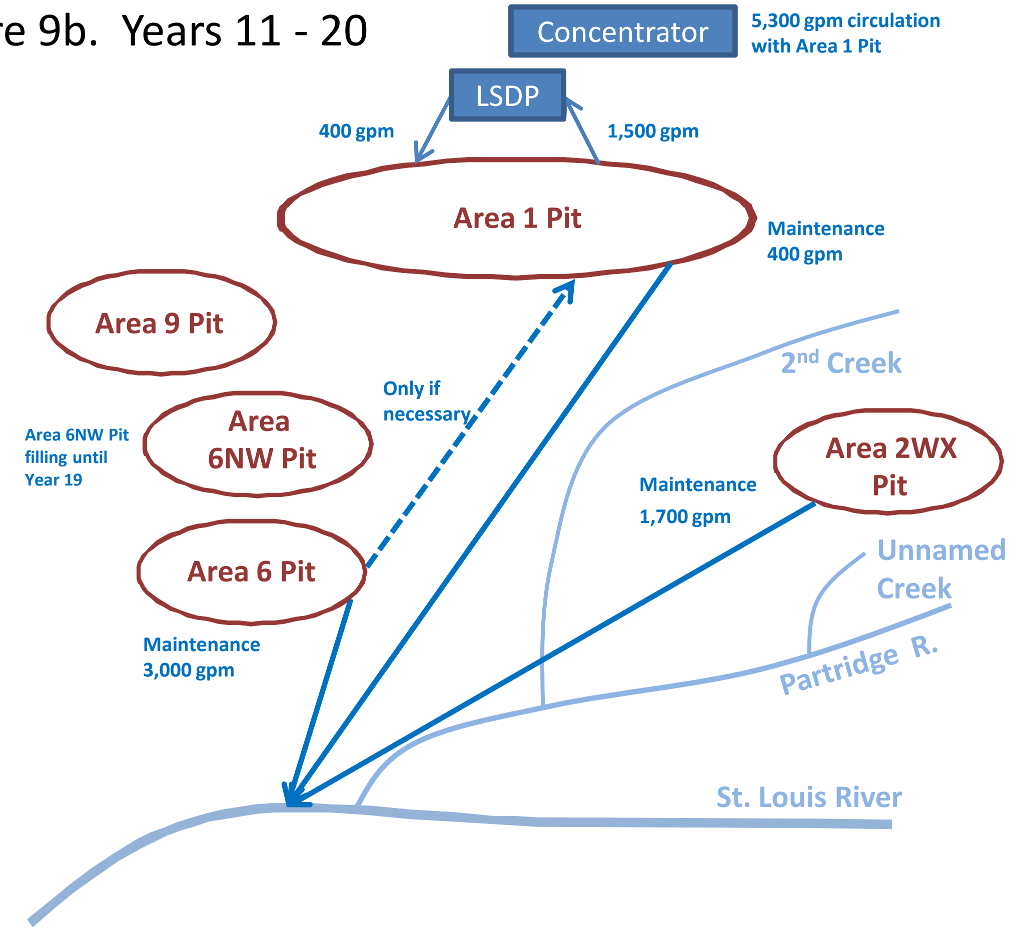
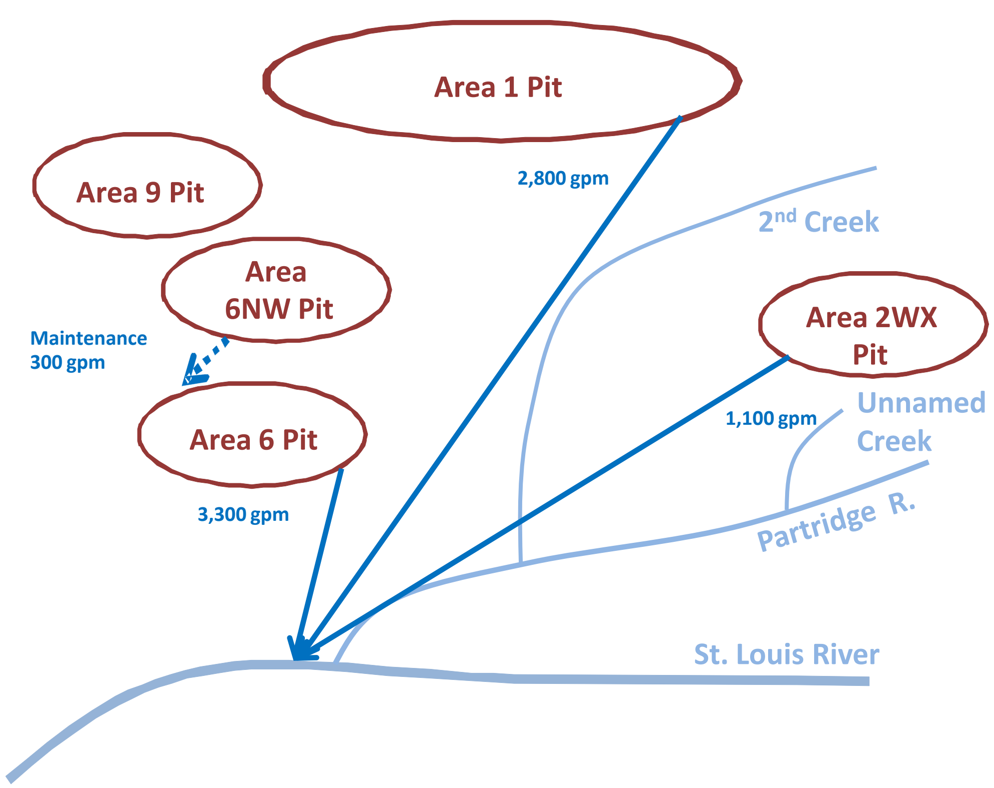



Figure 9c. Closure




Expected pumped water movement, as reflected in water balances

Alternative flow path for water movement

Passive water movement

*Assumes that a pipeline is constructed to the St. Louis River in Year 0. Only pits that are part of the Phase II Project are shown. Average annual flow rates are rounded to the nearest 100 gallons per minute (gpm). Seasonal variation is expected.*

Figures 9a – 9c

PROCESS WATER MANAGEMENT PLAN
FLOW FIGURES FOR
MINING ALTERNATIVE 2
Mesabi Nugget Phase II
Hoyt Lakes, Minnesota

Figure 10a. Years 0 – 3.5

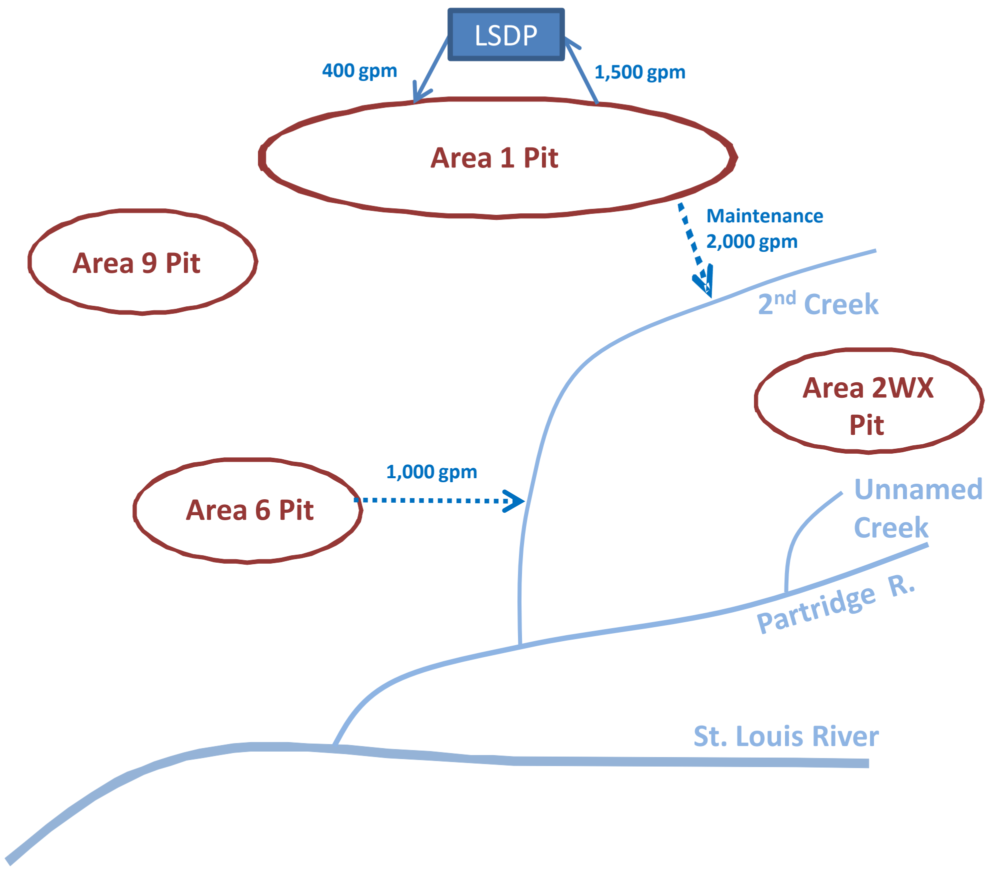



Figure 10b. Years 3.5 - 20

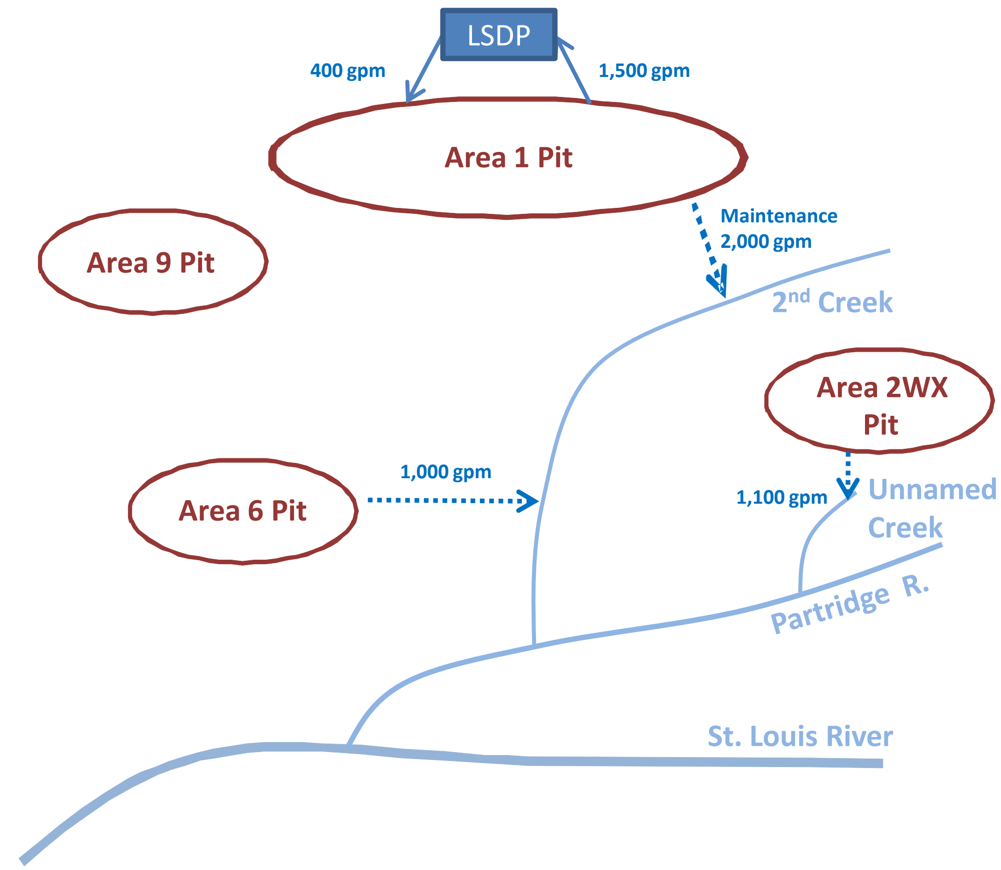
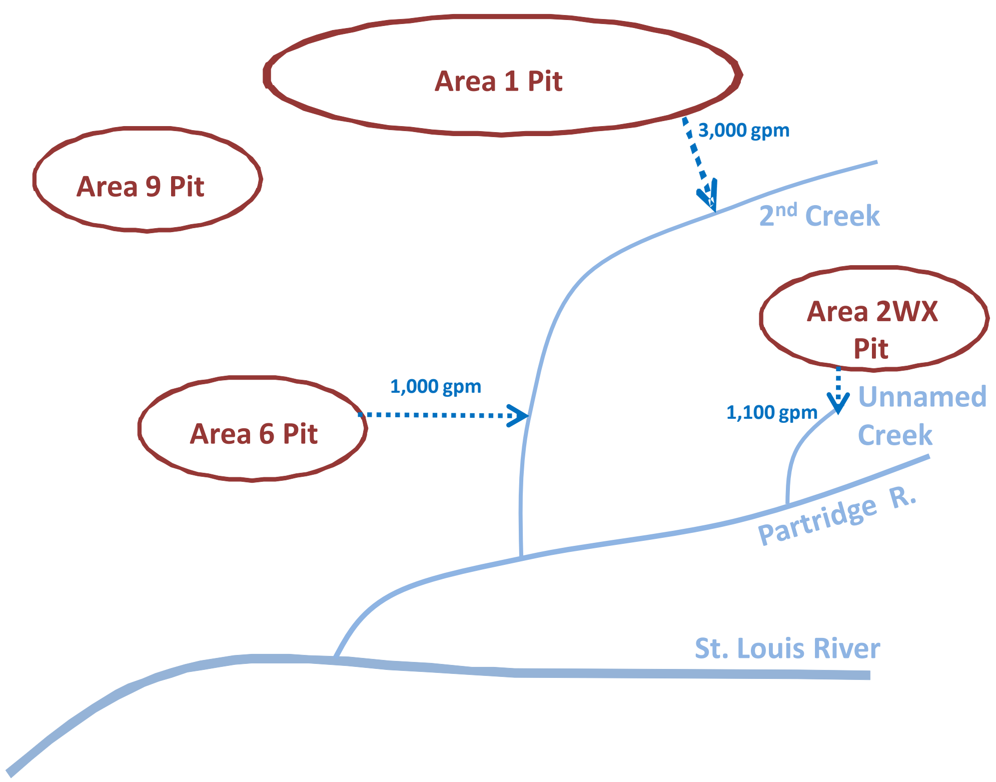



Figure 10c. Closure




Expected pumped water movement, as reflected in water balances

Alternative flow path for water movement

Passive water movement

*Assumes that a pipeline is constructed to the St. Louis River in Year 0. Only pits that are part of the Phase II Project are shown. Average annual flow rates are rounded to the nearest 100 gallons per minute (gpm). Seasonal variation is expected.*

Figures 10a – 10c

PROCESS WATER MANAGEMENT PLAN
FLOW FIGURES FOR
NO ACTION ALTERNATIVE
Mesabi Nugget Phase II
Hoyt Lakes, Minnesota

# Appendix A

## Discharge Monitoring

# 1.0 Discharge Monitoring

Mesabi Mining proposes to use a hydrograph-controlled discharge approach for its discharge of water from the Area 1 Pit, Area 2WX Pit, and Area 6 Pit to the St. Louis River. Compared to a fixed discharge rate, this approach will significantly lower the probability that water quality standards in the St. Louis River will be exceeded due to Mesabi Mining's discharge. This approach relies on real-time monitoring of the flow rates and specific conductance (SC) of both the discharge and receiving water. A regression between SC and other regulated chemical parameters was developed using existing data (Barr, 2009g), and will be updated using additional monitoring data as it becomes available (Barr, 2009m). Based on this information, the allowable discharge rate will be calculated to ensure that water quality standards are met at the end of the mixing zone. This document describes the methods for determination of the correlation between SC and hardness, alkalinity, total dissolved solids (TDS), and sulfate, and the methods for calculation of the allowed discharge rate.

This analysis was completed using data for the Partridge River rather than the St. Louis River. This was done primarily due to the limited monitoring data available for the St. Louis River. This approach is conservative due to the generally higher concentrations in the Partridge River compared to the St. Louis River. See Table 1-1 for this comparison (compounds of interest for this analysis are highlighted). Further, this analysis is intended to demonstrate the concept; actual compliance will rely on additional monitoring data gathered in the future. Therefore, this analysis demonstrates the concept using the Partridge River rather than the St. Louis River, and results in the same general conclusions.

**Table 1-1. Partridge River and St. Louis River Water Quality Comparison**

| | | Sample Date | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| **Chemical Name** | **Units** | **Total or Dissolved** | **Partridge River** | **Partridge River** | **St. Louis River** |
| Nitrogen, ammonia as N | mg/l | NA | 0.11 | 0.086 | 0.03 |
| Arsenic | ug/l | Total | 1.3 | 1 | 0.5 |
| Barium | ug/l | Total | 15 | 11.7 | 7.08 |
| Alkalinity, bicarbonate as CaCO3 | mg/l | NA | 127 | 79.7 | 47.7 |
| Bromide | mg/l | NA | 0.0858 | 0.00841 | 0.0055 |
| Calcium | mg/l | Total | 27.5 | 26.2 | 15.8 |
| Chemical Oxygen Demand | mg/l | NA | 55 | 50.2 | 54.2 |
| Chloride | mg/l | NA | 5.9 | 4.07 | 2.25 |
| Cobalt | ug/l | Total | 0.39 | 0.73 | |

| | | Sample Date | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| Chemical Name | Units | Total or Dissolved | Partridge River | Partridge River | St. Louis River |
| Cobalt | ug/l | Dissolved | 0.35 | 0.66 | |
| Fluoride | mg/l | NA | 0.19 | 0.17 | 0.11 |
| Hardness, total as CaCO3 | mg/l | NA | 279 | 173 | 104 |
| Iron | ug/l | Total | 798 | 903 | 941 |
| Magnesium | mg/l | Total | 51.1 | 27.3 | 15.7 |
| Manganese | ug/l | Total | 210 | 144 | 124 |
| Mercury | ng/l | Total | 4.1 | 14 | 2.1 |
| Mercury methyl | ng/l | Total | 0.753 | 0.23 | 0.07 |
| Molybdenum | ug/l | Total | 1.6 | 1.38 | 1.03 |
| Nitrate + Nitrite | mg/l | NA | 0.086 | 0.098 | 0.1 |
| Phosphorus, total | mg/l | NA | 0.013 | 0.013 | 0.026 |
| Potassium | mg/l | Total | 4.99 | 2.55 | 1.27 |
| Selenium | ug/l | Total | 0.55 | 0.63 | |
| Sodium | mg/l | Total | 11.8 | 6.92 | 4.4 |
| Solids, total dissolved | mg/l | NA | 351 | 238 | 159 |
| Strontium | ug/l | Total | 156 | 227 | 83 |
| Sulfate | mg/l | NA | 143 | 92.9 | 45.3 |
| Carbon, total organic | mg/l | NA | 18.8 | 18.4 | 20.4 |
| Dissolved oxygen | mg/l | NA | 9.097 | 89.67 | 7.33 |
| pH | su | NA | 7.6 | 7.48 | 7.56 |
| Specific Conductance | umhos/cm @ 25 °C | NA | 555.4 | 362.8 | 240 |
| Temperature | °C | NA | 16.76 | 15.88 | 19.88 |
| Turbidity | NTU | NA | 2.2 | 1.5 | 0.3 |
| Carbon, dissolved organic | mg/l | NA | | 18.6 | 20.4 |

## 1.1 Statistical Model Summary

Multiple statistical models were considered to determine the most appropriate model type for correlating SC to hardness, alkalinity, TDS, and sulfate in Mesabi Mining’s discharge and the St. Louis River. The statistical program R was used to analyze model fit (R Project for Statistical Computing, http://www.r-project.org), and R and Microsoft Excel were used to generate predictions of hardness, alkalinity, TDS, and sulfate, as well as their respective confidence intervals (CI). In this case, the “predictions” refers to the prediction of water quality based on the known specific conductance. For example, the concentration of alkalinity in the Area 1 Pit is predicted given a known specific conductance of the water. The "predictions" do not refer to the future water quality predictions as shown in the Dissolved Solids and Chemical Balance report.

The statistical models presented include a linear correlation of the grouped analytical data, and a non-interactive linear correlation, which weights the data from each water source individually. A linear correlation using log-transformed data was also considered, but rejected due to poor predictive ability at the low range of observed SC values with the other parameters of interest. A linear correlation using interactive factors (between the source water body and the calculated regression coefficients) was also considered, but rejected because the interactive factors were not statistically significant. Temperature was also considered as an independent variable, but there was little improvement in the correlation and the model made predictions that were consistently biased high for the Partridge River. These models are not presented further at this time, but may be considered in the future when additional monitoring data is available.

### 1.1.1 Linear Correlation Model

Figure 1-1 shows the relationship between SC and hardness, alkalinity, TDS, and sulfate using surface water quality monitoring data from 2008-09. Data from each of the four water bodies analyzed are combined into one data set to minimize the number of statistical models needed (i.e. one instead of four), and to add to the accuracy of the overall SC-parameter slope. A strong linear relationship is observed between SC and total hardness, alkalinity, and sulfate ($r^2$ = 0.94-0.95). Therefore, linear models with SC as the primary factor were judged to be appropriate starting points for empirical model building. Though the linear relationship between SC and alkalinity was weaker ($r^2$ = 0.74), a linear model was still thought to be the most appropriate starting point.

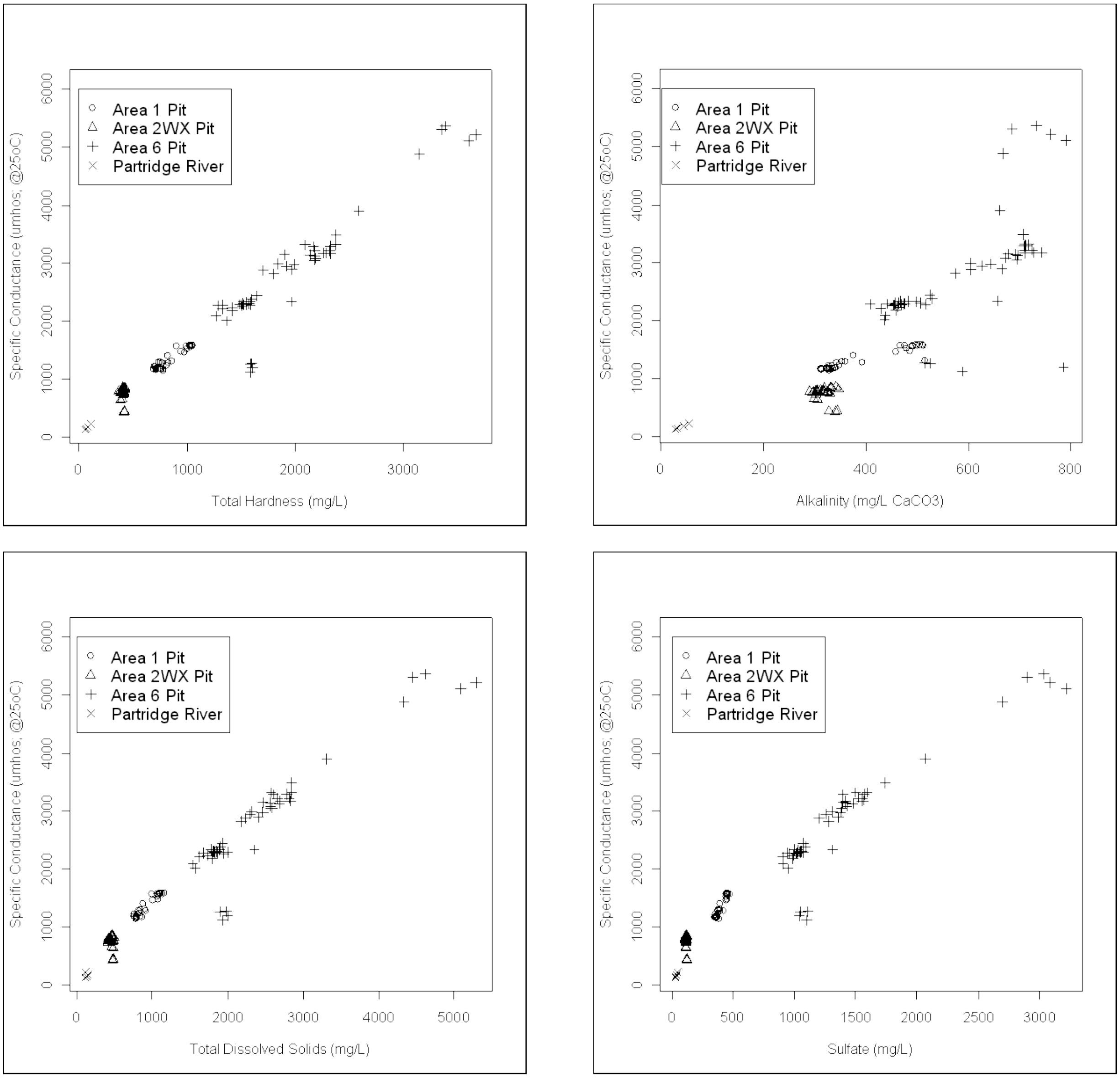



**Figure 1-1 Relationship between Specific Conductance and Water Quality Parameters**

### 1.1.2 Non-Interactive Linear Correlation Model

To improve the fit of the linear correlation, a basic non-interactive model was considered. In this model, additional regression parameters are added to adjust the y-intercept based on the individual water body. This model is described in Equation 1-1 below:

$$C_i \text{ (Hardness, Alkalinity, Sulfate, TDS)} = \alpha + \beta_1 * SC + \beta_i \qquad \textbf{1-1}$$

Where,

$C_i$ = concentration of one of the parameters of interest for location *i*

$\alpha$ = intercept

$\beta_1$ = regression parameter representing SC-parameter slope

$\beta_i$ = regression parameters for location *i*

SC = specific conductance of the sample measurement at location *i*

Table 1-2 summarizes the goodness-of-fit for the water quality parameter predictive linear models. The model produced an improved fit with the available data compared to the basic linear regression model (0.95-0.96 compared to 0.94-0.95; 0.82 compared to 0.74). Some of the additional regression parameters were not found to be statistically significant (i.e. a p-value < 0.05), meaning that they cannot be statistically distinguished from zero (i.e. no change from the basic linear regression model). Since the goodness-of-fit improved for each water quality parameter, this framework was retained as the base of the predictive model.

**Table 1-2. Goodness-of-fit of Non-Interactive Linear Correlation Models [1]**

| Dependent Variable | $r^2$ | F-statistic [2] | Non-significant coefficients [3] |
|---|---|---|---|
| Total Hardness | 0.96 | 745 | $\beta_{Partridge}$ |
| Alkalinity | 0.82 | 135 | $\beta_{2WX}$ |
| TDS | 0.95 | 606 | $\beta_{Partridge}$, $\beta_{2WX}$ |
| Sulfate | 0.95 | 582 | $\beta_{2WX}$ |

[1] Models were of the form: dependent variable = f(SC, location)

[2] All F-statistics are on 4 and 114 degrees of freedom

[3] Statistical significance is set at $p < 0.05$

A mass balance model can then be used to calculate the concentration downstream of the mixing zone. This mass balance is shown in Equation 1-2 below:

$$C_{mixed}\text{ (Hardness, Alkalinity, Sulfate, TDS)} = p_{Partridge} * C_{Partridge} + p_1 * C_1 + p_{2WX} * C_{2WX} + p_6 * C_6 \qquad \textbf{1-2}$$

Where,

$C_{mixed}$ = concentration of one of the parameters of interest at the edge of the mixing zone

$p_i$ = proportion of stream flow of location *i* of the total mixed stream flow

$C_i$ = concentration of one of the parameters of interest for location *i*

## 1.2 Estimation of Uncertainty

The uncertainty of each predicted value (e.g. alkalinity based on measured SC for the Area 1 Pit) is represented using the standard error from the regression model. The standard error for a linear regression is analogous to the standard deviation of a normal distribution mean. The variance of the predicted mean value is the square of the standard error (SE).

The variance of the blended water is then calculated as follows:

$$Var_{mixed} = p_{Partridge}^2 * Var_{partridge} + p_1^2 * Var_1 + p_{2WX}^2 * Var_{2WX} + p_6^2 * Var_6 \qquad \textbf{1-3}$$

Where,

$p_i$ = proportion of water from each source water *i* mixed in the Partridge River

$Var_i$ = variance of the water quality parameter for water body *i*

The calculation of the blended water quality parameter, then, produces a distribution defined by both the mean estimate and variance of the blended water.

Because the real-time proxy for the water quality parameter of interest (SC) should have a small probability of underestimating the actual value from the blended water, it is necessary to define a value for SC which behaves as a sufficient upper confidence interval. This value for SC needs to estimate the values for the other water quality parameters of interest (total hardness, alkalinity, TDS, and sulfate) in accordance with policy on water quality exceedances. EPA recommends a once in 3-year average frequency for excursions of both acute and chronic criteria.[1] Because the Project sampling regimen is not fixed (to be determined as part of the NPDES permitting process), the upper confidence interval must be a

[1] Technical Support Document for Water Quality-based Toxics Control, EPA, 1991, p. 36.

function of the number of allowed exceedances and the water sampling frequency, given that a higher frequency of sampling over the same underlying distribution increases the probability of producing an exceedance. As the sampling frequency increases and the tolerance for exceedances remains constant, the level of confidence the upper confidence interval also increases.

## 1.3 Estimating the Maximum Allowed Pit Discharge

In order to estimate of the maximum allowable pit water discharge, two input parameters in addition to the raw data used to calibrate the model are required: the level of confidence (1-2α) which is set based on the tolerance for exceedance; and the degrees of freedom (df) of the model, which is based on the number of data points. These input parameters are used in the inverse Student's t-distribution ($t_{inv}$), a function that produces a percentile scalar used to generate an upper bound estimate. In the initial step, the predictions of the water quality parameter of interest for the two (or more) blended sources of water and their variances are calculated as described in Sections 1.1 and 1.2.

The upper limit estimate of the concentration of the blended water at the $100*(1-\alpha)^{th}$ percentile, $C_{1-\alpha}$, can be calculated as:

$$C_{1-\alpha} = C_{blended} + Var_{blended}^{1/2} * t_{inv}(df, (1-\alpha)/2) \qquad \textbf{1-4}$$

This upper limit, $C_{1-\alpha}$, is then set to a constant equal to 80 percent of the state water quality standard in this example. Expanding this equation for discharge from one pit yields the following:

$$C_{1-\alpha} = p_1 * C_1 + (1-p_1) * C_{Partridge} + (p_1^2 * Var_1 + (1-p_1)^2 * Var_{Partridge}))^{1/2} * t_{inv}(df, (1-\alpha)/2) \qquad \textbf{1-5}$$

This equation can be solved numerically or using the quadratic formula. This solution yields a $p_1$ that represents the maximum proportion of volumetric flow in the mixing zone that the Area 1 Pit discharge stream can represent of the blended Partridge River water. Thus, the allowed Area 1 Pit discharge rate can be calculated given the measured SC in the discharge stream, measured SC in the Partridge River, and flow in the Partridge River are known. For cases with discharge from more than one pit, one of the source pit proportions must be fixed to determine the maximum allowable proportion from the other pit.

## 1.4 Implementation of Statistical Model

In order to demonstrate application of this methodology, an example calculation of the maximum mine pit discharge as a volumetric flow rate proportion of the total Partridge River flow is given below.

Scenario (Note: this scenario is not representative of predicted water quality):

- Water will be discharged from Area 1 Pit into the Partridge River.
- SC in Area 1 Pit sample is 1100 µmhos at 25ºC.
- SC in the Partridge River is 150 µmhos at 25ºC.
- Sampling is done monthly.
- Risk tolerance: more than one exceedance over a hypothetical 3-year sampling period is tolerated <5% of the time (this corresponds to a 98% CI for individual exceedances). This exceedance would be of 80 percent of the applicable water quality standard, thus making an actual exceedance of the water quality standard extremely unlikely.

After running the prediction function from the regression model, for each of the water quality parameters, the following central tendency estimates and standard errors are calculated.

**Table 1-3 Water Quality Parameter Predictions**

| Dependent Variable | Location | Estimate | Standard Error (SE) | Water Quality Standard |
|---|---|---|---|---|
| Total hardness ($mg/L\ CaCO_3$) | Area 1 Pit | 711 | 27.9 | 500 (3C) |
| | Partridge | 69.5 | 78.7 | |
| Alkalinity ($mg/L\ CaCO_3$) | Area 1 Pit | 379 | 12.6 | 250 (4A) |
| | Partridge | 37.9 | 35.5 | |
| TDS (mg/L) | Area 1 Pit | 716 | 41.1 | 700 (4A) |
| | Partridge | 108 | 116 | |
| Sulfate (mg/L) | Area 1 Pit | 269 | 27.2 | NA |
| | Partridge | 23.0 | 76.7 | |

These values, along with the level of confidence required, are input into a spreadsheet that calculates the maximum proportion that pits can contribute based on Equation 1-5. The maximum contribution calculated for each of the water quality parameters of interest is summarized in Table 1-4 below.

**Table 1-4 Maximum Pit Contribution Predictions**

| Dependent Variable | Maximum Allowed Contribution (Area 1 Pit Water) |
|---|---|
| Specific Conductance | 68.4% |
| Total Hardness (mg/L $CaCO_3$) | 25.0% |
| Alkalinity (mg/L $CaCO_3$) | 25.0% |
| TDS (mg/L) | 41.3% |
| Sulfate (mg/L) | NA |
| | |
| **Result (most restrictive)** | **25.0%** |

Because the most restrictive water quality standard drives the estimate, the maximum allowed contribution from the Area 1 Pit water is 25.0% of the volumetric flow rate, as derived from the estimated alkalinity concentration distributions. Contributions from Area 1 Pit exceeding this volumetric flow proportion will cause the likelihood of alkalinity exceedance to rise above that set by the risk tolerance level defined in the scenario. The Area 1 Pit will contribute approximately 9% of the volumetric flow in the St. Louis River during Mining Alternatives 1 and 2, meaning that the water management plan would result in compliance with surface water quality standards in this example.

## 1.5 Use of Additional Water Quality Monitoring Data

The accuracy of the linear regression model and the confidence intervals is limited by the amount of available data. The pit water qualities are expected to change through time (as described in the Dissolved Solids and Chemical Balance report); therefore the model will need to be continually refined as more data becomes available. In particular, the number of data points available to calibrate the model for background flow in the St. Louis River is currently limited.

Mesabi Mining will be required to monitor the water quality of its discharge and the St. Louis River as part of its NPDES permit and/or the Environmental Impact Statement requirements. This additional data can be incorporated with, or eventually replace, the baseline monitoring data. As more monitoring data is built into the calibration, the accuracy of the water quality parameter estimates in the river are expected to improve. As mentioned previously, additional monitoring data will allow for further exploration of the alternative models described briefly in Section 1.1.